Volume 6 April 1960 No. 4

Canadian Aeronautical Journal

CONTENTS

Published by the
CANADIAN AERONAUTICAL INSTITUTE
Commonwealth Building, 77 Metcalfe Street
OTTAWA

AN AIR TO GROUND TELEMETRY AND DATA REDUCTION SYSTEM — **W. R. M. McLellan**

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CANADIAN AERONAUTICAL JOURNAL
Vol. 6, No. 4: Page 126, April 1960

STRESS WAVES

Familiarization of a few basic concepts of st
dilatational and distortional, are discussed. T
free boundary is considered and some problem
The elementary solution for longtitudinal and t
Some uses of stress waves are indicated.

CANADI

AKEOFFS AND — **Dr. D. H. Henshaw**

esearch programme conducted jointly by The
td. and the Canadian Defence Research Board.

CANADIAN AERONAUTICAL JOURNAL
Vol. 6, No. 4: Page 119, April 1960

Dr. H. F. L. Pinkney

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CANADIAN AERONAUTICAL JOURNAL
Vol. 6, No. 4: Page 133, April 1960

POTENTIAL FLOW ABOUT AN AEROFOIL WITH A SPLIT FLAP — **Dr. P. Mandl**

A theoretical study of the flow about aerofoils with split flaps and circulation control by suction.

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Vol. 6, No. 4: Page 123, April 1960

TOWARDS STILL SHORTER TAKEOFFS A LANDINGS

A review of a four year STOL research progra De Havilland Aircraft of Canada Ltd. and the Ca

CANADIAN
V

AVIATION & NORTHERN DEVELOPMENT — **R. G. Robertson**

1960 Mid-season Meeting Dinner Address.

CANADIAN AERONAUTICAL JOURNAL
Vol. 6, No. 4: Page 116, April 1960

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Subscription—$4.00 a year. Single copy—50 cents.
Published monthly, except in July and August.
The Institute is not responsible for statements or opinions expressed in papers or discussions printed in its publications
All communications should be addressed to The Secretary, Canadian Aeronautical Institute, 77 Metcalfe St., Ottawa 4. Ontario, Canada.

Authorized as second class mail, Post Office Department, Ottawa

Printed by The Runge Press Ltd., Ottawa, Ontario, Canada

STOL RESEARCH

An RCAF Otter assigned to an STOL Research Project conducted jointly by the Defence Research Board and The De Havilland Aircraft of Canada Limited. **(See pages 119 to 122)**

EDITORIAL

A FUND OF REFERENCE

THIS is another issue of the Canadian Aeronautical Journal. Like its predecessors – and, no doubt, like many future issues – it contains five papers and the C.A.I. Log. No doubt you will allow it to lie around for a while, then glance through it, make a note of any of the papers that may later prove directly useful to you in your work, and then either stow it away or throw it away; at any rate you will forget about it.

Nowadays the flood of periodicals is engulfing us all and few of us have time to read more than a small part of the information that is thrust upon us. We have to be selective and to read only those papers or news items necessary to keep us abreast of the state of our respective arts. We must, perforce, miss a lot. We are living for today and indeed today we certainly have enough to keep us busy.

But this butterfly existence is not becoming to us. Times change and jobs change. And what does not interest us particularly today may be of considerable interest tomorrow. It is not altogether wise to throw away bits of information, however trivial they may appear to be in themselves; for in years to come we may want to refer to them. Admittedly the collection of periodicals and magazines presents a serious storage problem, and many of us throw them away month by month, because we know from experience that, if we stow them away for a time, we will certainly be compelled to throw them away eventually. However there are ways of minimizing this problem; one of them is to have the issues bound annually, without advertisements and cover sheets, and so to build up a library of bound volumes, which not only look respectable but are indexed, tidy and complete.

The collection and retention of trade magazines is fascinating and of great historical interest but, to the engineer, the journals of technical societies are far more important; for they are among the tools of his trade. An orderly collection of them can be of great value as a source of reference, and although individual issues may contain in themselves little of immediate use, the cumulative effect of an unbroken series assumes considerable significance. It is worth noting that a distinguished contemporary of the Canadian Aeronautical Journal is having its prewar and wartime issues reprinted and made available as bound volumes, to meet the demand for complete sets.

Since its inception the Canadian Aeronautical Journal has issued an index to each volume. (The volumes are based on calendar years.) Doubtless some readers and certainly many libraries have taken advantage of this service and have had their issues bound locally at the end of every year. But binding is inclined to be expensive if done volume by volume or in small quantities and, therefore, to encourage the practice, the Institute has made arrangements for the binding of volumes, in quantity, at a special price. The plan is that, in February every year, readers who wish to take advantage of the scheme should send in their issues of the previous year, with the index furnished with the January issue, and the Institute will arrange to have them bound and returned to them at $5.00 a volume. Each volume is a good-looking, hard-covered book about ¾ inch thick – a very different matter from the almost 2 inches thick collection of paper-covered individual copies. Of course this service will not come into effect until February 1961 but it is mentioned now so that readers can save their copies of 1960 issues for binding when the time comes. Matching volumes of previous years can of course be bound at the same time but the price will be a little higher.

Another feature which has been introduced to make the Journal more useful as a permanent fund of technical information is the supply of index cards with each issue. The practice of building up personal card indices is becoming more and more common among engineers. The cards supplied for the first time with this issue are adaptable, we believe, to indices already established or can be used to start new ones. A personal card index is a most useful thing; you can make your own notes on it, arrange it to suit your own way of thinking and generally develop it as a source of information which is more readily accessible to you, individually, than any index set up by a library.

In sum, the Canadian Aeronautical Journal is developing, bit by bit, a store of technical information, cumulatively of great value and significance. We must do what we can to make it handy and effective.

AVIATION AND NORTHERN DEVELOPMENT†

by R. G. Robertson*

Department of Northern Affairs and National Resources

It is not the most comfortable of tasks to speak on a subject you know little about to an audience that you suspect knows a great deal more about it than you do. Such I fear is my position. Notwithstanding that, I am very glad to present this paper to the Institute whose objective — the conquest of distance — is so important in northern development.

My own special interest, as you know, concerns Canada north of the 60th parallel. This part of our country has been largely ignored by us right up to the present. Canadians have been too fully occupied with problems of development closer to centres of population. We lacked the interest and the need to make use of the north. Moreover, few of its resources could support the costs of developing them and still compete on the markets of the world. That period is passing. Canada has become one of the world's great industrial and trading nations. The gap between the costs of northern production and market prices is steadily narrowing. We can foresee a time, not many years ahead, when this country and the world will want — and be prepared to pay for — the products that the north can provide. The question for us will be whether we have done all we can to take advantage of that situation.

Most of the critical problems in the north are economic, not technical. By this I do not mean that more technological advance is not needed. Far from it. It is of the greatest importance. However, the test of any new developments must be economic. The question of costs is the steady problem for the north. There are a number of factors which make economic activity in the north expensive, but of these by far the most important is distance. The answer to distance is transport, and the answer therefore to the basic problem of the north is to get transportation costs down.

This is not easy. A number of characteristics of the north, besides distance, combine to keep costs up. Population density is extremely low, and is likely to remain low for a long time to come. Population centres are scattered — and even when a good deal of development has occurred, they will continue to be scattered. The face of the north is not likely ever to glow with the full blush of population well spread across it. It is more likely to resemble the freckled countenance of a school boy. It will have spots and speckles of communities — and then areas of virtually no population in between. I think these factors — together with the enormous size of the north — have special significance for our aeronautical industry. It is about these I would like to speak for a few minutes.

The present stage in the north is largely a pre-development one. We are still locating and assessing our resources. Virtually all the development is still to come. In the pre-development phase, the role of the aircraft is enormously important. Exploration for oil and gas is going forward apace and will expand greatly in the next few years. In most of Alberta and Saskatchewan similar exploration can rely largely on ground transportation. In the north this is much less true. The road system is simply not there. In the Yukon and Mackenzie valley last summer oil exploration required the services of about 60 aircraft and crews. When similar exploratory work begins in the Arctic Islands — where about 130,000,000 acres have been applied for under oil and gas permits — the reliance on aircraft will be equally great, perhaps greater.

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†Dinner address read at the Mid-season Meeting of the C.A.I. in Edmonton on the 21st February, 1960.

*Deputy Minister

The other major resource of the north is metallic minerals. For them, the role of aviation is likely to exceed its role in oil and gas exploration. In the vastness of the north, the foot-slogging prospector cannot, by his unaided efforts, cover enough ground fast enough. The airborne magnetometer has done much to help. More and more, detailed mapping that can be done or assisted from the air, detailed geological study through the use of helicopters and other low speed planes, and aerial techniques, especially devised for the north, will have to do the preliminary work of discovery and assessment.

We are getting into other tasks where aviation can help us greatly. An international convention drafted in Geneva in 1958 gives to each country the right to develop the resources of any continental shelf lying off its shores. Canada has the longest coast line in the world. Very large continental shelves lie off our coasts — especially in the Atlantic and the Arctic Oceans. We know almost nothing about them and nothing about their resources. Off our northern coasts we have done virtually no hydrographic investigation. We are starting. Last year helicopters were used to assist hydrographic work off Baffin Island. Their operation enabled the time required for the job to be cut down sharply. In the Arctic Ocean we have a new continental shelf expedition — relying on aircraft for support, and, again, on aircraft to speed its operations. These are only scratches on the surface — or perhaps "ripples" would be a better term for this beginning of off-shore exploration. It must increase greatly in years ahead.

In all of these fields of determining and locating resources in the vastness of our northern area, I am convinced that we shall rely increasingly on aircraft. Only through their use and the techniques adapted to them will we be able to cut agonizing years off the task of preliminary exploration work.

Let me turn now to the place of aviation in the more general field of transportation in the north — the movement of people and goods for the ordinary purposes of life and industry.

We are starting on a road system for the north. There are, however, limits to the practical scale of road development. The Northwest Territories and Yukon, between them, represent 40% of the area of Canada. An adequate network of roads will be very costly to build and will take a long time to complete.

Roads are also inflexible. They cannot be moved from one location to another as the area develops — and if anyone knows precisely where all the major developments in the north are going to be ten or twenty years from now, I would like to meet him. Roads are a must in the north, but they involve a lot of problems and they cannot be the whole answer.

Railways are unexcelled for hauling very large tonnages overland at minimum cost. Nothing else can touch them for that. There will certainly be a need for railways in the north — the projected line to Great Slave Lake is the outstanding example — but they clearly cannot meet the whole transport problem.

Movement by water is the principal means of surface transportation in much of the north, notably in the Mackenzie District and the high Arctic. It suffers from numerous drawbacks. It can operate only in the short summer, at the most for three or four months. On the Arctic coast, the season is shorter still. But even within the limits of the season, ships can never make a direct contribution to transportation for most inland areas.

Pipelines will undoubtedly play an important part in oil development when it comes on a commercial scale — and for gas. They may even have wider uses in future, but obviously they are not a general and flexible means of transportation.

This leaves aircraft. Some of you may have noticed a small item which appeared in the Canadian Press the day before Christmas about the production of the last Norseman aircraft. The heading in my newspaper was "Bush Plane Era Ends". I don't believe it. The era of the "bush plane" will not end in the north for a long time yet. In fact I feel confident that we have ahead of us, for many, many years, the greatest application of the aeronautical industry to the development of the north.

Of course, the contribution of aircraft to northern development has not been limited to small machines of the bush plane type or to specialized survey and supply services. It is just as important to get people and goods to and from the north as it is to move them around once they are there. Scheduled runs using modern long-range equipment are now reaching into the Arctic at points as far separated as Inuvik and Frobisher Bay. Airfields and air services are steadily being improved to assist them.

Costs on these long runs are at least as important as they are on other services, and it is a tribute to the efficiency of your industry and of the companies operating in the north that the whole history of scheduled services has been one of steadily decreasing ton-mile costs. This is being achieved, I understand, both by skilful organization and by willingness to invest in equipment well suited to the job in hand. I have read with interest of the impressive performance of the new CL-44 air freighter which seems likely in the future to make a further contribution to reducing these costs. The development of this aircraft, which is likely to be used throughout the world, is but the most recent of a long series of triumphs for Canadian designers and manufacturers.

It is not going too far to say that there have been two periods in northern history — before the aeroplane and since the aeroplane. Movement by air produced a revolution. That revolution is by no means over. Undoubtedly it will take on a new character, but the advantages of airborne vehicles for the north are so great that new applications will surely come. Other means of transport are route-bound and inflexible. Aircraft can travel nearly anywhere. They can annihilate space and distance — even in the magnitudes in which they exist in the north. Their use in the exploratory and pre-development phase is assured. Beyond that stage, and for the normal purposes of development, the question is the extent to which aircraft can be adapted to the special requirements of the north.

One great need is a carrier that retains the advantages of present air services, but can bring costs down, or alternatively a carrier that can operate like a truck or a train, but at a lower optimum volume and with less fixed

investment. These alternatives really amount to the same thing; it seems clear that whichever approach is used we will have to get "off the ground".

Such a carrier — or complex of carriers — would be especially valuable for shuttling cargo between inaccessible locations and sea or river ports, or the ends of road or rail lines. Most such inaccessible locations will be mine sites — which might be as little as fifty miles or as much as four hundred miles from the closest economical surface transportation.

It seems to me unlikely that further refinement of aircraft types now operating will be the final answer to this problem. Our present aircraft are designed primarily for other purposes. The answer may be an entirely different kind of vehicle. I have been most interested in the experimental work which has been done with the Rotodyne, Aircar and Hovercraft. These may be the first expressions of ideas that can be used in the north. The concept of a vehicle which does not operate at a great height, requires only a minimum cleared track on land or muskeg, and can also use rivers as its highways, seems to hold great possibilities for the needs of the north. On shuttle work we might even get to the point where pilotless carriers would prove practical and economical.

At any rate there is in the north plenty of scope for new designs directed to the specific problems of transportation in undeveloped and isolated regions.

It would take someone with much more insight into the economics of your industry than I have, to state with authority the extent to which demand in the north can support the development costs which will be involved in designing and building the types of airborne carriers that may be best suited to the problems there. I make only two suggestions. First, development in our north is gathering momentum. Population remains small, but in percentage terms it is now growing faster than in any Canadian province. There is a great deal of investment interest in oil possibilities, in minerals and in other economic activity. The market to be considered in the north is not today's market, but the expanding demand of the coming decades. This will be on a very different scale.

The second point is that the problems in the north are not unique in their essential character. There are still large areas in other parts of the world where surface transport is inadequate and may not be the best final answer. There are many places other than northern Canada where the cost of service to interior regions is so high that it has so far precluded development.

It is perhaps significant that aircraft designed for work in remote areas in Canada are currently providing useful services in many other parts of the world. Few other countries share the Arctic with us, but many have similar problems of undeveloped surface communications, limited airport facilities and small scattered populations. Australia and South America come easily to mind, and the names of Canadian planes — the Norseman, the Beaver and the Otter — are household words there as they are in our own northern territories. In parts of Asia and Africa there are other large areas that share these basic problems.

If Canadian engineers and designers can continue to find answers to these problems in Canada, I suggest to you that their products will find markets in other parts of the world that, like the Canadian north, are awakening to new phases of development and growth.

Impressive responses to major challenges are a tradition within your industry. You met the challenge of designing aircraft that could provide reliable service back in the days when planes were constructed of wooden batts and wire. You met a tremendous challenge during the war. You met the challenge of conversion to peace-time demand in the late 40's and 50's. I suggest to you that the transport needs of the north, and indeed of the nine-tenths of Canada that is under-developed, now provide a challenge for the industry in the 1960's and the 1970's.

In the future, the north will fill an increasingly important place in the Canadian economy. The nation and the world will have need of its resources — provided the problems of cost can be met. Ways to move goods in and out of the north more cheaply than we can do today would represent a contribution to the strength and prosperity of Canada even greater than those your industry has already made.

The essential thing is to refuse to allow ourselves to be bound by preconceptions or by the way things have been done in the past. The past will not give us all the solutions to unlock the northern future. Inventiveness, ingenuity, bold experiment and a willingness to take a chance with new ideas — these will be the keys to success for northern development, and for the role of aviation in it.

ANNUAL GENERAL MEETING

OTTAWA

24th and 25th May, 1960

TOWARDS STILL SHORTER TAKEOFFS AND LANDINGS†

by Dr. D. H. Henshaw*

The De Havilland Aircraft of Canada Limited

SUMMARY

A review of a four year STOL Research Programme which is being conducted jointly by The De Havilland Aircraft of Canada Limited and the Canadian Defence Research Board.

INTRODUCTION

During the last four years a research programme has been conducted by De Havilland Canada, with the assistance of the Defence Research Board, to assess the aerodynamic, performance, stability and control problems associated with short takeoff and landing aircraft. On the basis of a study of various methods for obtaining the desired STOL performance, it was decided to proceed with an experimental programme aimed at the exploitation of aircraft using propellers in conjunction with powerful flaps. The Otter aircraft employs powerful double-slotted flaps and, furthermore, very large power-on lift coefficients have been demonstrated. The potential of this aircraft was, therefore, such as to lend itself to the development of a special flight test vehicle for the study of the dynamic problems associated with STOL flight.

The STOL Otter with flaps in the UP position. The leading edge flaps are fixed but are intended to simulate the geometry of the movable type. Note the slotted elevators used to increase the effectiveness of the horizontal tail.

AERODYNAMICS

Flaps

In the initial phases of the experimental programme, measurements were made of the aerodynamic characteristics of the standard Otter. Subsequently, the aircraft was fitted with enlarged flaps with novel aerodynamic features to magnify their effectiveness.

The researches reported above were aimed at the development of aerodynamic techniques for the development of adequate lifts and drags for the STOL manoeuvres. It was extremely gratifying to note that it had been confirmed that the Otter and Caribou type of aircraft had outstanding potential for development. Advanced STOL performance was indicated for aircraft that were mechanically simple and economically powered. It was evident that the STOL aircraft would show a marked economic advantage over the VTOL types of aircraft.

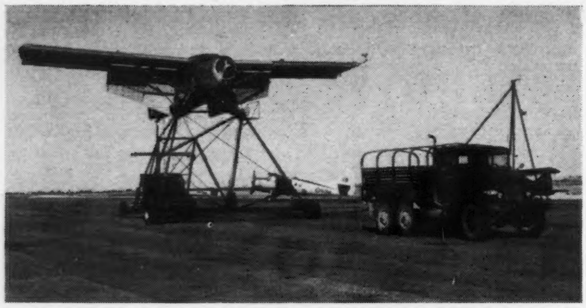
Our studies have shown that by careful and novel design of the flap slot geometry, it is possible to use the propeller slipstream as a source of high pressure air for boundary layer control purposes. Thus the action of the propeller slipstream on the flaps may be described in terms of direct and indirect effects. The direct effect involves the passage of the high velocity air over the flaps with a resulting lift and drag that exists even at zero flight speed. The indirect effect involves a spreading of the slipstream on the lower surface of the wing in such a way as to result in a passage of high velocity air through the flap slots over a considerable portion of the flap span. This flow has no indirect effect at zero forward speed (i.e. no VTOL application). At forward speed, however, these slot-flows induce an improved flow of air over the flaps and so increase markedly the lift capabilities of the wing.

We were, therefore, very encouraged in our STOL studies to note that the nature of propeller slipstream and flap flows is such as to provide advantage to the STOL machine. The economics of the STOL aircraft can therefore be better than one would ordinarily predict. The STOL machine will compare more favourably with both VTOL and conventional aircraft than one would predict with conventional analysis.

At the time of issuance of the second formal report on our STOL studies, a suitable combined lift and drag capability had not yet been demonstrated. The subse-

†Received 17 March, 1960.

*Research Aerodynamicist



The high trestle rig, designed to minimize ground effect and to test the aircraft at heights associated with takeoff and landing manoeuvers, is shown here being towed at a speed of 35 knots. This enables the study of aerodynamic characteristics at typical flight speeds.

quent developments were, therefore, aimed firstly at attainment of improvement of lift and drag. Then detailed studies were carried out to assess the static stability and control problems.

These new tests showed that the stability problems were such as to require modification of the existing flap system. The troubles were traced to roughness in the flow going over the flaps. This gave rise to unsuitable flows over the tail combined with an inadequate lift capability.

Study of the problem led to a flap redesign. One of the key changes here was the addition of a special flexible extension on the trailing edge of the fixed part of the wing. This device directed the flap slot-flows down over the flaps and so improved the flow pattern. Another key change was the incorporation of a small flap in the inboard portion of the large trailing flap. This flap operated in the slipstream and when deflected to large angles gave the high drag needed for landing. Once the drag was produced with this flap, it was possible to reduce the angular deflection of the other flap components. The result was a flap system with adequate lift, drag and stability characteristics.

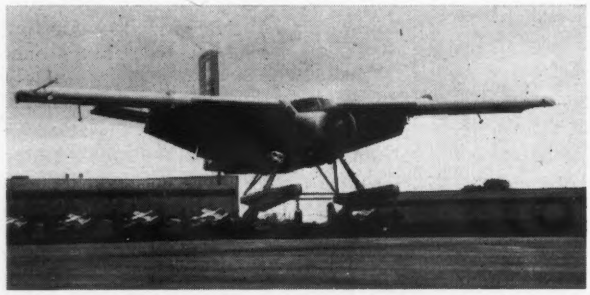
It was perhaps somewhat surprising that these changes of flap design should simultaneously solve so many problems. The developments were accomplished with only eleven test runs with the test stand.

Subsequently the test programme was exclusively devoted towards the development of design information for the manufacture of the flight test vehicle. Twenty-four more runs were carried out on the test stand to provide the multitude of aerodynamic coefficients required to establish the aircraft performance, stability, control and structural loading characteristics.

The Otter being towed on the low rig. Note the tow rope is attached to one side of the rig, thus preventing any air disturbance from the truck interfering with the tests.

CONTROL

In the control studies, analysis of aileron and rudder capabilities indicated a requirement for some form of boundary layer control. The practical application of boundary layer control techniques had not previously been undertaken at De Havilland Canada. The requirement existed for design information that could be obtained by experimental model studies. A model was built and mounted on a truck. By driving the truck at various speeds, the desired range of test speeds was obtained. A fair effort was required here to develop a boundary layer control scheme adapted to the requirement of the flight aircraft. The model tests were considered quite adequate and no further full-scale testing was undertaken for aileron controls.



The aircraft is seen here maintaining low altitude at an airspeed of 35 knots. Flaps are about 60° (full design deflection position is 90°). Based on the large area, the wing at this speed has a lift coefficient of 4. Lower speeds will be possible at larger flap deflections — partly because of the improved flap lift and also because the ailerons will be dropped to generate extra lift.

Tailplane

Some of the control investigations were carried out on the full-scale aircraft. These studies showed a requirement for a further increase of tailplane power to balance and control the aircraft. Testing was carried out with a modified Otter tailplane employing a revised aerofoil more suited to very low speed flight and an attempt was made to use vortex generators to increase elevator power. This tailplane was inadequate. A larger, more powerful tailplane was designed on the basis of this experience, using design information obtained in the Caribou development. The accelerated pace of the programme did not allow any testing of this revised tailplane. The initial tailplane studies had shown, however, that problems such as buffeting and stability have so far been adequately predicted on the basis of these early tests and so, to expedite the programme, it was decided to proceed without further testing.

The full-scale control studies did reveal a rudder buffet problem with the standard Otter rudder when the flaps were deflected. This was successfully cured in experiments with a modified rudder used for boundary layer control experiments. In these tests it was determined that boundary layer control was effective in increasing the rudder power. It was noted, however, that

At a glance the airflow shown here, with the engine inoperative, appears very good, but actually gave a poor lift because of the stagnant region created behind the flaps as indicated by the smoke. Whereas the smoke indicates the separated nature of the flow, the wool tufts on the flap surfaces and also 12 inches the above flap surface show a smooth attached flow. (Aircraft is headed into a steady 20 mph wind during this test.)

the rudder power was dependent on elevator angle. This adverse interference effect between elevator and rudder was found to be more severe for the boundary layer control rudder than for the conventional rudder. A fin and rudder design was therefore undertaken, aimed at alleviating the adverse interference effects. This involved mounting the tailplane low on the fin; the desired increase of tailplane height was then obtained with dihedral. Once again, the programme was expedited by omitting tests of the arrangement designed for the flight aircraft.

Aileron

Aileron testing was carried out with conventional Otter ailerons on the test stand aircraft. As these were found to be inadequate for this particular STOL application, boundary layer control ailerons were incorporated.

PERFORMANCE AND STABILITY

In the performance and stability analyses, tests were carried out to assess the aircraft lift, angles of attack and flap angles. The quantity of data required to predict the aircraft characteristics is unusually large because of the strong dependence of all these characteristics on the engine power. In the data processing, we were very fortunate in being able to process the data using IBM punched card techniques.

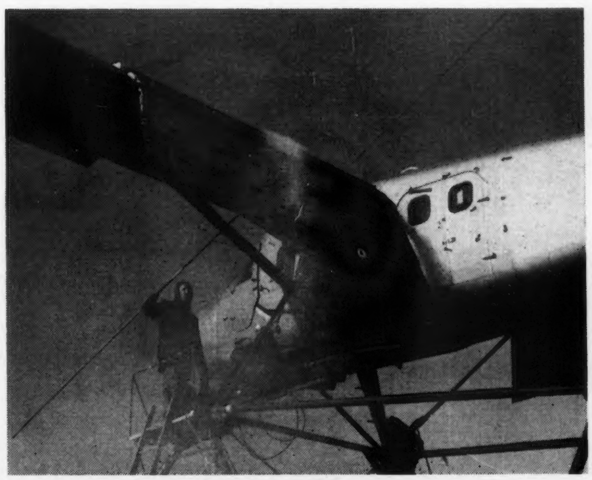
In the above tests, measurements were made of flow speed and direction of potential locations of the horizontal tail. These data, combined with the above force data, allowed prediction of the longitudinal static stability of the flight aircraft.

The experimental effort in acquiring all of the above data is rather large and it seemed prudent to carry out some flow visualization tests to ascertain in detail the flow characteristics. If undesirable characteristics were found, the necessary modifications could be incorporated in the design before the test programme had proceeded very far.

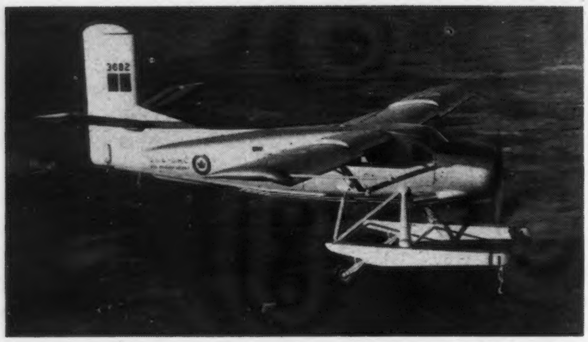
The use of smoke for flow visualization was very effective. A special smoke producer was devised and this proved to be a powerful device for the study of the flow field. The generator produced large quantities of smoke that could be directed from a 3 inch diameter flexible hose. Injection of this smoke into the various regions around the aircraft proved to be very illuminating. For example, the boundary layer control effects of the slip-stream flow over the flaps were clearly demonstrated. In addition, many instances of misleading indications of surface tufts were noted. Demonstration of the location and intensity of trailing vortices was also valuable. A requirement for modification to the wing leading edge was demonstrated. Here, the very large flap lifts caused a strong upflow and flow separation at the wing leading edge. In some later experiments with the aircraft on the low stand, it was noted that the ailerons approach closely to a region of disturbed flow. The smoke tests indicate that some types of STOL aircraft may experience difficulty with lateral control during the final phases of the landing manoeuvre. Fortunately, this problem does not appear to be present with our flight aircraft.

Another feature of the flow clearly demonstrated by the smoke, is the large downwash that can occur close to the ground. In tests on the low stand, it was shown that slipstream flow is deflected towards the ground and then spreads out quite markedly. The action is such as to allow a large downwash to exist even with the aircraft close to the ground. Thus, with this particular arrangement of aircraft, the ground effect on downwash is so small that it is anticipated adequate control can be achieved with manually operated elevators. Severe ground-effect control problems have been experienced in other STOL configurations which do not have this desirable characteristic.

The determination of structural loadings on the flaps occupied a considerable portion of the testing. Since these flaps incorporated special features to increase the



In this case, with the engine running, the lift is very good. Note that the flow through the slots is at high speed as indicated by the rather light smoke density. The smoke is being swept down towards the camera with no tendency to accumulate behind the flaps. (Again headed into a 20 mph wind.)



The unusual four wheel landing gear was devised as an economical method of simulating a tricycle gear. The tricycle gear, or equivalent, is necessary to give a good flow over the tail when the aircraft is operating on the ground.

influence of the slipstream, slipstream effects required evaluation in considerable detail. As is usual with pressure distribution measurements, the quantity of data was very large. Once again, however, IBM punched card techniques permitted calculation, plotting and integration to be carried out precisely, rapidly and with minimum cost.

Throughout the testing period, design and manufacture of the flight aircraft was being carried on. It is true that many design decisions were made before the data were available. Fortunately, no difficulties on this score arose and so some considerable time was saved on this account. It was possible to schedule the design, fabrication and structural testing of components in the most expeditious manner.

Towards the end of the programme, wind tunnel testing of a model of the STOL aircraft was undertaken as a joint effort of De Havilland Canada and the National Research Council. The data from extensive tests will be of a broad interest because it rarely happens that model test data are available for comparison with the results of an extensive flight test programme. The interest in the wind tunnel is particularly great because information on wind tunnel constraint corrections for STOL aircraft is essentially non-existent. On the basis of the wind tunnel and flight tests, it will be possible to assess the potentialities of the wind tunnel for testing in the general STOL, VTOL field.

FLIGHT TEST

The final phases of the test programme have involved the flying of the STOL aircraft. This aircraft has flown on nineteen occasions to date. Initially the flights were carried out close to the ground in flights along the runway. Recent flights have been carried out at altitudes of several thousand feet with flight durations well over an hour.

The flight programme initially served to confirm the accuracy of the test stand data, but now the flights indicate some very interesting characteristics as regards the dynamics of stability and control parameters with STOL aircraft.

In the next three months, the flight test programme will have provided information on lift, drag and static stability. In addition, studies will be made of the dynamic characteristics of the aircraft, which will be particularly valuable because the STOL Otter has singularly excellent stability characteristics.

CONCLUSION

In conclusion, the last four years of research and testing have led to the development of a flap system having the required lift, drag and stability characteristics. Tests have also been performed to permit the development of suitable, specialized controls for the ailerons, rudder and elevator of the flight test vehicle. Structural loading measurements have been made for the mechanical design of the flaps. The whole effort has culminated in the fabrication and flight testing of an aircraft. These flight tests will be of value in assessing the accuracy of test stand and wind tunnel data and, in addition, provide invaluable data on the dynamic stability and control characteristics. We are pleased to note that many abridgements of the test programme have been successfully carried off with an ensuing saving in both time and money.

LIST OF MEMBERS

Cards, which will be used in the preparation of the List of Members 1960, were mailed to all members during March. The List will be made directly from the information given on these cards. Members are asked to ensure that their cards are completed in detail and returned to the Secretary by

13th MAY, 1960

POTENTIAL FLOW ABOUT AN AEROFOIL WITH A SPLIT FLAP†

by Dr. P. Mandl*

National Aeronautical Establishment

THIS paper summarizes a theoretical study of the flow about aerofoils with split flaps and circulation control by suction which was carried out in collaboration with experimental work at NAE. The mathematical development of the theory is described in detail in References 1 and 2. (Reference 1 is a simpler approach which has been extended in Reference 2.)

The physical background of the problem may best be described with the aid of a photograph (Figure 1) taken in the NAE water tunnel of a 9% thick, symmetrical, two-dimensional aerofoil at zero incidence with a split flap deflected 45°. As a means of boundary layer control, suction is applied through a slot located on the upper surface of the flap below the trailing edge of the aerofoil. The general flow reattaches to the upper surface of the flap forming a closed region (cavity). Inside the cavity the fluid is not at rest but is accelerated due to the presence of the standing vortex. Since the flow both inside and outside the cavity is characterized by favourable pressure gradients, the application of the theory of potential flow seems justified. However, near the leading edge where the flow separates, the results obtained by potential flow theory may be expected to be unrealistic; no attempt has been made to include separation effects in the analysis.

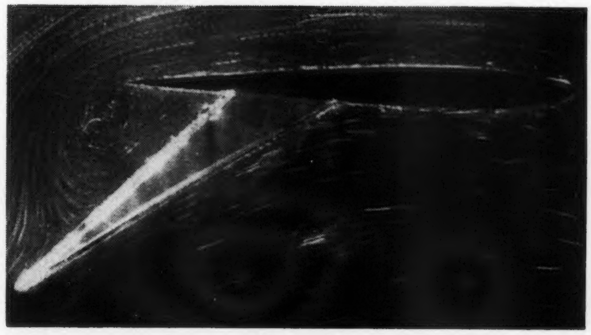


Figure 1
Flow picture of two-dimensional aerofoil

BASIS OF CALCULATION

To simplify the theory, the combination of aerofoil and flap is idealized by a straight-line configuration, suction being considered due to a sink located on the upper surface of the flap. Figure 2 shows this idealized configuration together with some of the principal streamlines in the physical (Z—) plane.

To effect systematic calculations of the flow, the region external to the aerofoil and flap in the physical plane (Figure 2) is mapped conformally onto that external to the unit circle in the circle (t—) plane (Figure 3). The transformation between these two planes is obtained by considering the aerofoil and the flap as a collapsed five-sided figure and by applying an extension of the Schwarz-Christoffel mapping theorem[3]. The resulting transformation is of the form

$$Z = K\frac{(t+1)^2}{t}\left[\mu + i\nu\frac{t-1}{t+1}\right]^n\left[\mu - 1 + i\nu\frac{t-1}{t+1}\right]$$

where K, n, μ and ν are constants related to the geometry of the aerofoil flap combination.

It should be pointed out that in order to make the circular boundary a streamline, an image vortex at the inverse point of the standing vortex and a source at the centre of the circle must be added to the flow. The resulting mapping of the aerofoil and the flap onto the

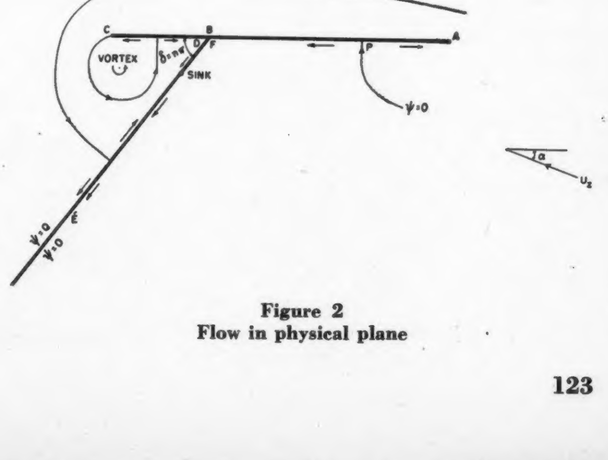


Figure 2
Flow in physical plane

†Received 26th January, 1960.
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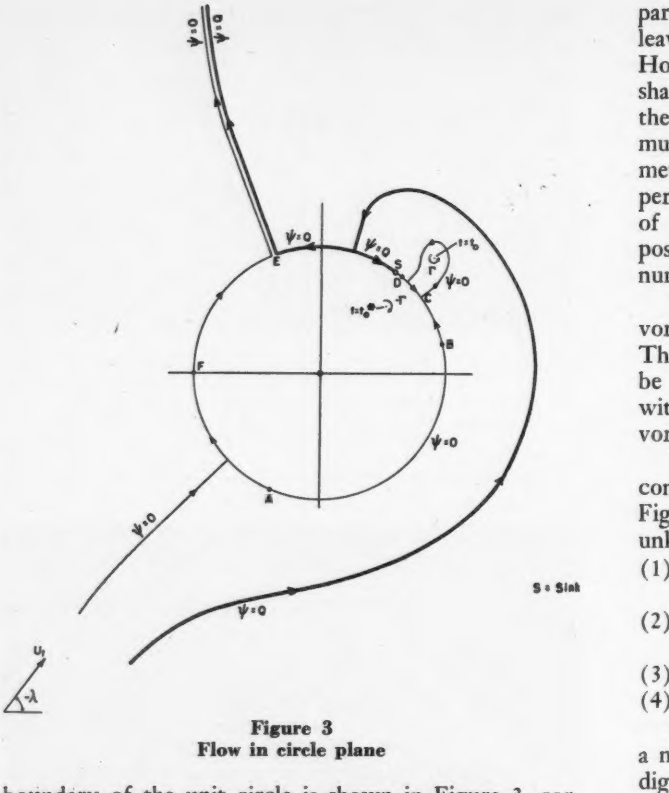

Figure 3
Flow in circle plane

boundary of the unit circle is shown in Figure 3, corresponding points being labelled by the same letter.

A fundamental question arises here in connection with the calculation of the flow about solid boundaries having more than one cusp edge. In the problem of finding the flow about an aerofoil with or without conventional flap, the circulation is the only adjustable parameter; it is determined by the condition that the flow leaves the trailing edge tangentially (Kutta condition). However, since an aerofoil with a split flap possesses two sharp edges (i.e. the trailing edges of the aerofoil and the flap) a difficulty arises, because a Kutta condition must be applied at two places. Hence an additional parameter is required to determine the flow uniquely. Experiment suggests that this parameter is the circulation of the standing vortex (Figure 1). (This method may possibly be generalized to configurations having any number of cusp edges.)

The standing vortex is considered as a potential flow vortex in equilibrium with the remainder of the fluid. The condition for equilibrium is that the vortex centre be a stagnation point of the basic flow, i.e. the flow without the vortex but including that due to the image vortex and the source (Figure 3).

The equilibrium conditions together with the Kutta condition applied at the two trailing edges (C and E, Figure 2) provide four simultaneous equations for the unknowns:

(1) The radial co-ordinate of the centre of vortex in the circle plane
(2) The polar angle of the centre of vortex in the circle plane
(3) The over-all circulation about the aerofoil
(4) The circulation of the standing vortex

Since these equations are rather complicated in form, a numerical solution was obtained on the NAE Bendix digital computer. A unique equilibrium position of the vortex was found which agreed quite reasonably with experiment.

Application

By expressing the transformation (1) in a form suitable for numerical calculations the streamlines in the physical plane were obtained from those of the related

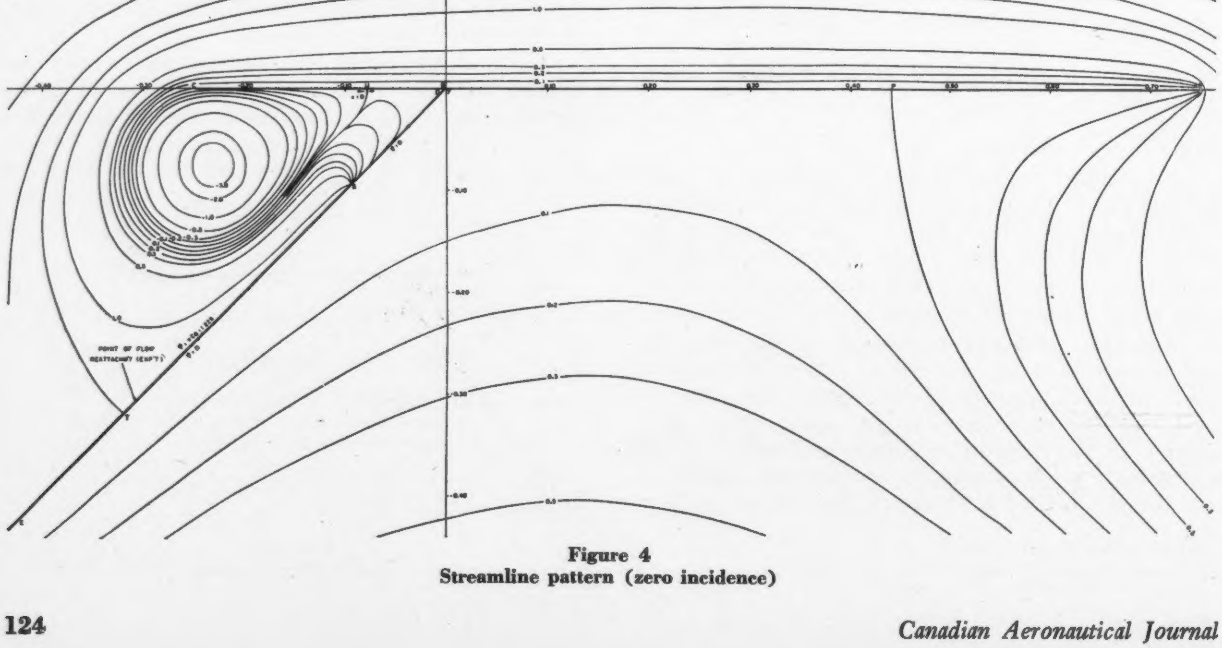

Figure 4
Streamline pattern (zero incidence)

flow in the circle plane. The calculated streamlines displayed in Figure 4 may be compared with the flow picture shown in Figure 1. (The aerofoil and flap geometry in the experiment is the same as that considered by the theory, except for the finite thickness and the round leading edge.) Theory and experiment agree well in the region aft of the trailing edge and in the angle formed between aerofoil and flap. However, there are some significant departures near the leading edge and the front stagnation point where boundary layer effects make themselves felt and there are some indications of leading edge separation.

The streamlines labelled $\psi = 0$ and $\psi = \pi C_Q = 1.225$ (C_Q = suction coefficient which is proportional to the suction rate) are of particular interest, because they separate the flow field into two distinct regions (see also Figure 3): all streamlines within the region bounded by $\psi = 0$ and $\psi = 1.225$ terminate in the sink and are thus affected by suction, while those outside do not. The streamline $\psi = 1.225$ forms the boundary of the cavity, follows the upper surface of the flap and then leaves the tip of the flap tangentially, thereby forming part of a sheet across which the stream function is discontinuous; the discontinuity in ψ is equal to the volume flux removed by the sink.

The zero streamline which forms the major part of the boundary of the aerofoil and the flap divides the flow field inside the cavity into two separate regimes: one chiefly controlled by the vortex and another by the sink.

Comparison of results

It is of interest to consider the variation of the lift coefficient with incidence for a fixed flap deflection. For this purpose the lift coefficient is plotted against incidence for a 45° flap deflection (Figure 5) along with results obtained by the simpler theory[1] which ignores the standing vortex. Also shown are experimental lift coefficients obtained from the flow photograph (Figure 1) by integrating the velocity along a large contour surrounding both aerofoil and flap.

The results indicate that the predicted lift coefficients are considerably larger than the experimental ones, although the lift curve slopes agree, and that the effect of the standing vortex is to increase the lift even further. The apparent discrepancy between theoretical and experimental lift coefficient is probably due to flow separation near the leading edge. It can be shown by a rough calculation based on the theory of Reference 4 that the lift coefficient is considerably reduced if the effect of the leading edge bubble is taken into account. Other factors ignored in this investigation, such as the finite thickness or the influence of the tunnel constraint, can be shown to widen the discrepancy.

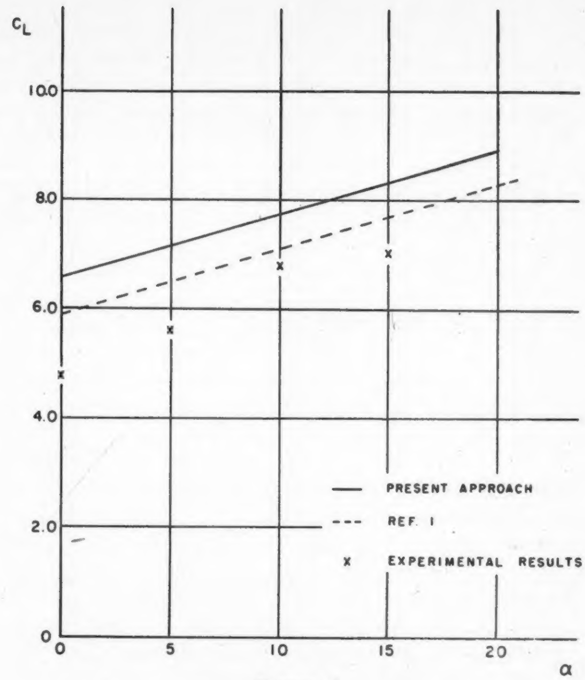

Figure 5
Variation of lift coefficient with incidence
(flap angle = 45°)

CONCLUSION

This paper shows that by properly taking account of the standing vortex, potential flow theory may be applied to calculate the streamline pattern about an aerofoil with a split flap. The theory confirms that aerofoils with split flaps used in combination with circulation control yield large lift coefficients. In spite of the divergence of some of the results from experiment, the theory may be useful from the designer's point of view in indicating basic trends of some of the major variables, such as location, size and deflection of the flap, position and strength of the sink, etc.

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(1) Whitehead, L. G., Cheers, F., and Mandl, P. — *Flow about Aerofoils with Split Flaps with Application to Circulation Control by Suction,* NAE Laboratory Report LR-226, April, 1958.

(2) Mandl, P. — *Effect of Standing Vortex on Flow about Suction Aerofoils with Split Flaps,* NAE Laboratory Report LR-239.

(3) Jeffreys, B. S., and Jeffreys, H. — *Methods of Mathematical Physics,* Third Edition, Cambridge University Press, p 424, 1956.

(4) Wood, L. C. — *Theory of Aerofoils on which occur Bubbles of Air,* R and M No. 3049.

AN AIR TO GROUND TELEMETRY AND DATA REDUCTION SYSTEM†

by W. R. M. McLellan*

Royal Canadian Air Force

INTRODUCTION

WITH the rapidly increasing capabilities of aircraft, missiles and rockets for higher and faster flight, the requirement for in-flight information, on their aerodynamic behaviour, has also considerably increased. Associated with these recent advances in airborne and space flight is the tremendous demand for knowledge of conditions in the new environment.

Each flight undertaken by these modern vehicles produces information or data which influences design, instrumentation and data requirements, for subsequent flights. It is therefore essential, especially in development or evaluation flight tests, that the required information is made available with maximum accuracy, reliability and speed.

Various techniques have been developed for the collection of this data, the most popular, for various reasons, being the art of telemetry. Telemetry systems convert the mechanical and electrical parameters to be analyzed to voltage analogs and transmit these voltages to distant locations for convenient data reduction and subsequent analysis.

Any flight test programme is conducted to obtain information; therefore, the efficiency of a programme is dependent on the efficiency of the system which collects this information. The prime objective in the system design is therefore reliable acquisition and fast data reduction. The required accuracy may vary according to the nature of the data involved, but for some parameters accuracies are required beyond the capabilities of the present state of the art.

METHODS OF TELEMETRY

The parameters to be measured are translated to analog voltages by transducers. A transducer is an electro-mechanical device which, when actuated by a mechanical change, produces an electrical output.

In order to transmit the voltage output from the transducers to the ground installation, a frequency modulation (FM) type radio link is usually employed. However, transmission of the transducer outputs to the ground installation by modulating separate RF carriers would require a formidable data link. A technique of multiplexing is employed, whereby the data voltages are mixed, either by time sharing or sub-carrier frequency sharing, and the RF carrier frequency modulated by the resultant complex signal.

Frequency sharing systems employ a sub-carrier oscillator with each transducer. Each transducer is associated with a different sub-carrier frequency, depending on the anticipated frequency response of the data. The data voltage frequency modulates the sub-carrier frequency. The frequency modulated sub-carriers are mixed linearly to form the complex signal which frequency modulates the RF carrier frequency. This technique produces an FM/FM type telemetry signal.

Recovery of the data is achieved by presenting the complex signal, after demodulation, to a number of discriminators. Each discriminator selects a sub-carrier frequency and translates the data to the original voltage analog.

The sub-carrier frequencies are sufficiently separated to ensure that no overlap occurs. IRIG (Inter-Range Instrumentation Group) standards state the centre frequency of each sub-carrier and its limits of modulation.

Time division systems employ sampling techniques, whereby each transducer output is sampled for an increment of time. The output from the sampling commutator is a series of samples of the analog voltage data. These pulses of constant width and varying amplitude frequency modulate the RF carrier, in which case the type of telemetry signal is PAM/FM.

A technique employed which greatly increases the accuracy of the system is pulse width or pulse duration modulation (PDM). The voltage amplitude samples are translated to pulse duration samples of constant amplitude and of width proportional to the value of the sample. The pulses frequency modulate the carrier to produce a PDM/FM signal.

The most usual type of telemetry signal is PDM/FM/FM where one or more of the sub-carrier frequencies of an FM/FM system contains the data in PDM pulses.

†Received 15th January, 1960.
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To recover the data from a PDM/FM signal they are received and demodulated, producing the PDM. The PDM pulses are decommutated and translated from pulse duration to pulse amplitude. The original voltage analogs are reproduced by passing the pulses through a system of lowpass filters. In the case of PDM/FM/FM the sub-carrier is recovered containing the PDM/FM signal after demodulation. If the signal after demodulation contains a complexity of mixed sub-carriers, the PDM is recovered after passing the signal through the system of discriminators.

For still greater accuracies, PCM/FM techniques are employed whereby each voltage sample is translated to a pulse code, usually binary. Until quite recently PCM/FM systems, although theoretically very attractive, were rarely used for airborne telemetry, the size, weight, power consumption and complexity being too great and dependability uncertain. With recent miniaturization and design techniques, however, PCM systems should become popular in the very near future.

DATA PROCESSING AND REDUCTION

The usual procedure, employed at most ranges to handle telemetered data, is to record the demodulated complex signal on analog magnetic tape and, after completion of a test, play back the tape, extract pertinent data and produce the required information from subsequent computation. The analog magnetic tape has a number of separate tracks, each track recording a different type of signal, such as the demodulated telemetry signal, speech and the range time signal. The magnetic tape recorder is a high grade precision instrument, designed to minimize errors due to tape speed variations, wow and flutter. Although such errors can be minimized by careful design and manufacture, electronic techniques are necessary to effect further correction during tape playback.

The complex signals, recovered from the tape during playback, are presented to a processing system for channel separation and visual graphical recording as raw data. The recorders are multi-track precision instruments and may be of the pen or photographic type, depending on the data characteristics and the information required. Slowly varying or quasi-static data may be recorded on pen recorders, but data containing frequencies over about 50 cps must be recorded by instruments which introduce negligible friction losses.

When the selected data have been processed and recorded in the graphical form, it is necessary to give the recordings meaning. The operation, whereby these tracings are translated into meaningful information, is known as data reduction. If this operation is carried out manually, it is a tedious and time consuming task and various automatic and semi-automatic devices are usually employed.

Modern system design indicates quite a departure from these concepts, with greater utilization being made of up-to-date digital techniques. Experience has also shown that much more information can be collected with much less telemetered data. No matter what system concept is employed, however, the telemetered data must eventually be reduced to a scaled and corrected graphical record or meaningful tabulation.

Referring back to the statement that the prime objective is reliable data acquisition and fast data reduction, it is obvious that the time taken to produce meaningful information from the raw data must be drastically reduced; the analog magnetic tape playback concept is not the answer. The ideal system would accept the telemetered data and produce the necessary information immediately. This Utopian state of the art is still prohibitive but we can advance considerably towards it.

Reviewing typical tests involving acquisition of data by telemetry, the type of data is almost invariably 90% quasi-static in character, the remaining 10% of the data containing higher frequencies. Data reduction involves the editing, scaling and linearizing of about 95% of this data, the 5% eventually entering a digital computer for more sophisticated computation. The linearizing and scaling is also usually carried out using the digital computer.

Utilizing modern digital techniques, it is now feasible to carry out linearizing and scaling at a rate which provides an immediate graphical presentation of the required information, thus not only effecting substantial economy but also dispensing with the analog tape playback operation. As all the data is in a digital form, on-line digital computer entry can be achieved, thus economizing further and maintaining an extremely higher level of accuracy and efficiency.

A discussion follows which is intended to describe this modern data acquisition and reduction concept. An attempt is made to prove that both these functions must be integrated and considered as one system in modern system design.

AN AUTOMATIC SYSTEM DISCUSSED

Data acquisition

For the purposes of this discussion, it is assumed that the types of telemetry signal to be received and processed are PDM/FM, PDM/FM/FM and FM/FM. It is also assumed that American IRIG standards will be maintained in the design for a modern system, which will be required to operate with Canadian or American airborne systems.

IRIG has been assigned the task of promulgating new or revised telemetry standards, by the IRIG Steering Committee. This committee represents the majority of American Department of Defense test ranges.

Telemetry data acquisition and processing has now reached a fairly stable format, in which the data channels are eventually separated for graphical recording. From this point however, modern concepts depart from the old and data are stored directly in digital code, usually on magnetic tape. Recording directly on digital magnetic tape ensures that no further erratic data degradation is possible, except by bit drop-out and this is negligible in a well-designed system.

It is highly practical to install the data acquisition section in a separate location to the data reduction section, as data acquisition is usually associated with trial operations. Personnel involved in operational trials function with greater efficiency when other personnel, not directly involved in the trials, are not present.

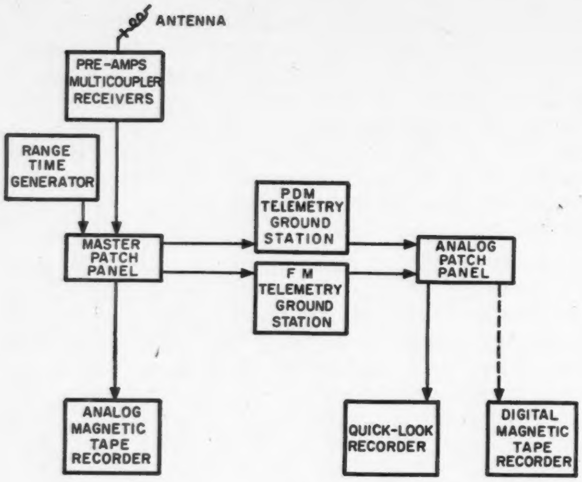

Figure 1

The basic system is therefore as shown in Figure 1, where the telemetry signal is demodulated and recorded on the analog magnetic tape recorder. This recorder should be included in digital systems as operational back-up only and need serve no other purpose. Equipment should be dual to this point to give 100% operational back-up. In the event of ground equipment failure after this point in a system, the analog recorder may be used to recover the data, inferior data being better than no data at all.

The processed analog data channels are recorded in the raw, unscaled, uncorrected state by the telemetry signal monitoring, or "quick-look" oscillograph recorder and, concurrently with both the analog magnetic tape and the oscillograph recording, the data are collected by the digital magnetic tape.

The data at the analog patch panel, which now includes a range time signal, must be converted to a digital format before recording on the digital tape. Also, a sampling technique must be used, which samples all the data at a rate which ensures negligible data degradation. The digital magnetic tape should be installed in the data reduction section which, it is agreed, is situated at some distant location.

As American IRIG telemetry standards are being maintained, the system can be designed to handle standard signals. Therefore, a PDM type signal will contain a serial pulse train of 900 samples per second, which may be in the form of 30 data channels, each sampled 30 times per second, or 45 channels, each sampled 20 times per second (30×30 or 45×20). An FM/FM type signal will contain up to 12 frequency modulated sub-carriers, selected from the table in Figure 2. Channels 14 to 18 may frequency deviate $\pm 15\%$ providing adjacent channels are omitted. These five channels, referred to as channels A to E, extend the frequency response to 2,100 cps.

Thus, the maximum number of channels which may appear at the analog patch panel is 53 (41 PDM & 12 FM). Only 41 of the 45 PDM channels contain data, as two channels are for synchronization and two for zero and full-scale reference.

Multiplexing and digitizing

The separated analog data channels at the analog patch panel must be time-division multiplexed and the resulting serial pulse train of data samples digitized. The serial train of digitized samples must be conveyed to the data reduction centre and recorded on a digital magnetic tape.

The processed data from the FM ground station will be in the form of up to 12 separate data channels, each presenting a continuous time series to the multiplexer. The PDM data, after translation to serial amplitude pulses, may be multiplexed with the FM data in the commutated condition. The multiplexer should therefore have 13 inputs to 13 multiplexer channels.

The amplitude samples emerging from the multiplexer must be held constant, using a sample and hold technique as shown in Figure 3a, for a sufficient time to permit the digital "word" to be formed. During recovery at the data reduction centre, the waveform shown in Figure 3b will be produced. If this waveform is passed through a low-pass filter, the original data can be recovered.

Regarding the rate at which the original analog data channels must be sampled by the multiplexer in order to reduce data degradation to a minimum, it can be shown that a sampling process, which samples average signal amplitudes over a period Δt, introduces a frequency dependence of the recovered signal, of the form:

$$\frac{\sin \pi \beta \frac{f}{F}}{\pi \beta \frac{f}{F}}$$

$F =$ the sampling rate

$\beta =$ that part of the sampling period $1/F$ over which the sample is held, and

Sub-Carrier Band	Centre Frequency (cps)	Lower Limit (cps)	Upper Limit (cps)	Maximum Deviation	Frequency Response (cps)
1	400	370	430	±7.5%	6.0
2	560	518	602	,,	8.4
3	730	675	785	,,	11
4	960	888	1,032	,,	14
5	1,300	1,200	1,398	,,	20
6	1,700	1,572	1,828	,,	25
7	2,300	2,127	2,473	,,	35
8	3,000	2,775	3,225	,,	45
9	3,900	3,607	4,193	,,	59
10	5,400	4,995	5,805	,,	81
11	7,350	6,799	7,901	,,	110
12	10,500	9,712	11,288	,,	160
13	14,500	13,412	15,588	,,	220
14	22,000	20,350	23,650	,,	330
15	30,000	27,750	32,250	,,	450
16	40,000	37,000	43,000	,,	600
17	52,500	48,560	56,440	,,	790
18	70,000	64,750	75,250	,,	1,050
A	22,000	18,700	25,800	± 15%	660
B	30,000	25,500	34,500	,,	900
C	40,000	34,000	46,000	,,	1,200
D	52,500	44,620	60,380	,,	1,600
E	70,000	59,500	80,500	,,	2,100

Figure 2

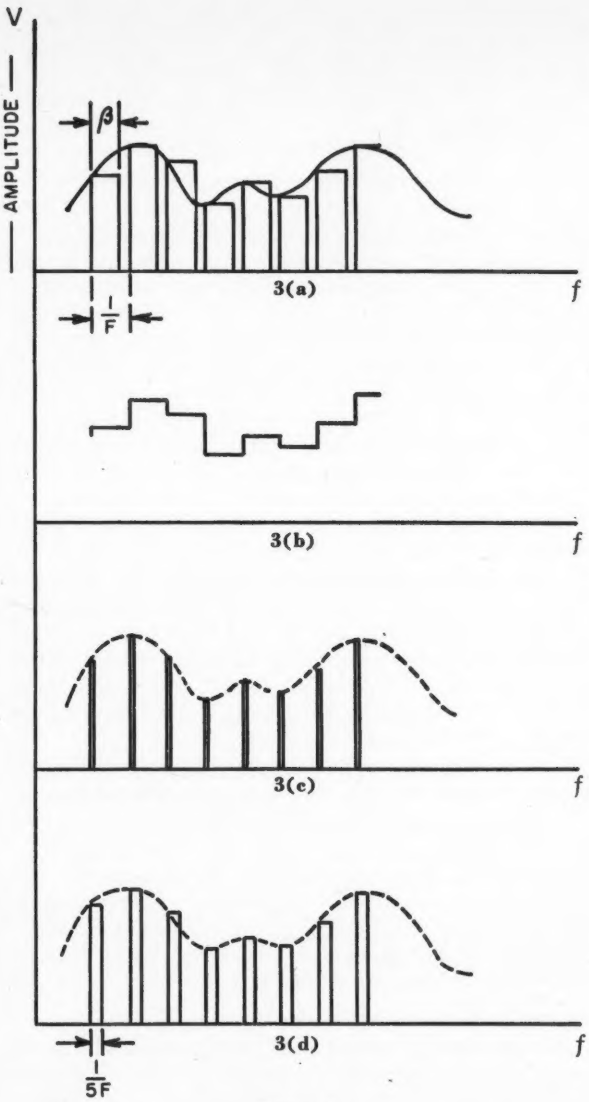

Figure 3

f = the highest frequency component (Fourier component) of the data signal

For small amounts of data degradation, $\frac{\sin x}{x}$ can be approximated by:

$$\frac{\sin x}{x} \approx 1 - \frac{x^2}{6}$$

If degradation of ϵ is permissible, the minimum condition is:

$$\epsilon \lesssim \frac{x^2}{6}$$

$\therefore$ if

$$\beta = 1$$

then

$$\epsilon \lesssim \frac{\left(\pi \frac{f}{F}\right)^2}{6}$$

S is the samples per cycle of $f = \frac{F}{f}$

percentage degradation $\leq 100 \frac{\pi^2}{6S^2}$

i.e. for 1% error

$$S = \sqrt{\frac{100}{6}}\,\pi$$

$$= 12.8 \text{ samples per data cycle}$$

A sampling rate of 13 times the data frequency is prohibitive as the pulse repetition frequency after conversion to digital code would be excessive. However the sampling rate can be reduced to $2f$ if each data sample contained in the waveform Figure 3b is instantaneously sampled and the resulting impulse samples passed through ideal impulse filters.

Employing practical filters and sampling techniques, and sampling at three times the data frequency with a sample hold duration of $1/5F$ as shown in Figure 3d, data can be recovered with less than 0.5% error. A practical multiplexer should therefore sample each data channel at approximately four times the data frequency.

The sampling rates for the 12 multiplexer channels can therefore be set at four or more times the 12 highest FM data channels, thus ensuring that any of the other 12 FM data channels will be sampled at a sufficiently high rate. The commutated PDM may be sampled by the 13th multiplexer channel at the 900 samples per second rate.

A serial pulse train emerges from the multiplexer. A convenient format, which ensures proper synchronization, is shown in Figure 4. A block contains four frames of 24 samples or, after digitizing, binary words. Each

	Block			
Word	Frame	Frame	Frame	Frame
1	1	1	1	1
2	12	12	12	12
3	11	11	11	11
4	10	10	10	10
5	12	12	12	12
6	9	9	9	9
7	2	2	2	2
8	12	12	12	12
9	11	11	11	11
10	10	10	10	10
11	12	12	12	12
12	3	3	3	3
13	13	13	13	13
14	12	12	12	12
15	11	11	11	11
16	10	10	10	10
17	12	12	12	12
18	9	9	9	9
19	4	5	4	5
20	12	12	12	12
21	11	11	11	11
22	10	10	10	10
23	12	12	12	12
24	6	7	8	Block End Pulse

Figure 4

Channel	1	2	3	4	5	6	7	8	9	10	11	12	13
Samples per block	4	4	4	2	2	1	1	1	8	16	16	32	4

Figure 5

multiplexer channel is therefore sampled at the rate shown in Figure 5.

For example, Figure 6 shows the 12 highest FM data frequencies which would be involved and the multiplexer sampling rates which could be allotted to them. The serial amplitude pulse train of 900 samples per second from the PDM telemetry signal enters multiplexer channel 13. The samples per second applied to each channel should be four or more times the data frequency. Channel E is allotted the highest sampling rate of 8,400 sps and the remaining sampling rates are easily found from Figure 5. The total samples made per second is therefore 25,190 sps.

The final over-all sampling rate can be set at this or some greater value, the chosen rate will depend on the capabilities of subsequent equipments. For example, if we now digitize to an eight bit binary code we would produce 25,190 × 8 or 205,520 bits per second. Thus, using a non-return-to-zero (NRZ) system, each bit would have an approximate duration of 5 microseconds. We could therefore increase considerably the over-all sampling rate if a sample need be described by eight bits only.

However, it is necessary to include the range time signal and word synchronization, therefore additional bits must be included in each word. If we take two bits for synchronization, one bit for range timing and one bit for parity check, these four bits reduce our data bits to four.

In order to maintain an accuracy compatible with the remainder of the system and allow for future improvement in data acquisition accuracy, a ten bit or an eleven bit binary system should be used. From examination of pulse packing density capabilities of high grade digital magnetic tape recorders, and analog-to-digital conversion techniques, it can be seen that a sixteen bit system is quite feasible. Thus, a sixteen bit word would contain:

2 bits for word synchronization,
1 bit for parity check,
1 bit for range time signal,
1 bit for identifying a PDM word, and
11 bits for a data sample.

FM Telemetry Channel	FM Frequency (cps)	Multiplex Channel	Samples per sec
E	2,100	12	8,400
C	1,200	11	4,200
A	660	10	4,200
12	160	9	2,100
11	110	1	1,050
10	81	2	1,050
9	59	3	1,050
8	45	4	525
7	35	5	525
6	25	6	260
5	20	7	260
4	14	8	260
	PDM (900 sps)	13	1,050
		Block End Pulse	260

Figure 6

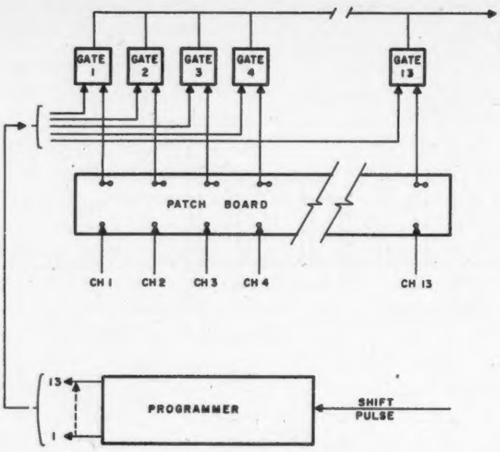

Figure 7

Therefore, an accuracy of 1 part in 2,047 is easily obtainable.

The prf emerging from the multiplexer, if the additional bits are added to the data bits within the apparatus, would therefore be 25,190 × 16 = 403,040 pulses per second. Increasing the over-all sampling rate to 31,250 sps, produces a convenient 500,000 serial pulses per second, and the bit duration, using a NRZ system, becomes 2 microseconds.

The multiplexer could take some form, as shown by Figure 7. A convenient shift pulse rate control may be obtained from the 900 sps PDM pulses.

The 500,000 pulses per second may now be recorded on a digital magnetic tape recorder for subsequent semi-automatic data reduction. Concurrently with this recording the data may be linearized and scaled and, after reconversion to analog, a graphical presentation of directly intelligible information produced.

Automatic linearizing and scaling

Before commencement of a test, each transducer on the vehicle, associated with a channel which will require the linearization operation, is calibrated. The transducer non-linearities are combined with the over-all system non-linearities, including the output recorders, and a calibration for the system obtained. The system is to automatically apply these corrections to the data at the data reduction section and produce real-time, visual, meaningful recordings for immediate inspection.

Although all the data channels can be automatically corrected during a test, operational experience has shown that only up to ten channels of linearized data need be produced, and the remaining channels recorded as raw analog traces. This immediate inspection of corrected meaningful data is an impossibility, using the analog magnetic tape playback concept.

Our system must have a de-multiplexer in the data reduction section, capable of separating the data channels from the serial pulse train of 500,000 pulses per second, extracting selected channels for data linearizing, and sending the remainder to the quick-look recorders. This de-multiplexer presents a simple problem in logic; however, the data channels, which are to be linearized and scaled, require special treatment.

In order to reduce pulse packing densities on the digital magnetic tape, and enable a fast adder to be employed in the linearizer, the 500,000 pulses per second serial pulse train is passed through a serial to parallel converter. Thus sixteen bits are recorded on 16 magnetic tape tracks at the 31,250 pulses per second rate.

Linearizing can best be carried out by installing the linearizer before the de-multiplexer and applying a linearizing correction to every sixteen bit data word. Only those data words, which are samples of the channels to be linearized, are acted on by an actual value, the remainder have nothing added and go to the de-multiplexer unchanged. This arrangement is shown in Figure 8.

It is first of all necessary to make a decision on the degree of linearization to be applied. In the case of a system employing eleven binary bits to describe a sample, the maximum value of a sample would be 2047 ($2^{10} + 2^9 + 2^8 + 2^7 + 2^6 + 2^5 + 2^4 + 2^3 + 2^2 + 2^1 + 2^0$). It is unnecessary to use eleven bit linearizing coefficients, as the least significant bits would have negligible effect and non-linearity to the extent that the most significant bits would be required is not anticipated. A practical linearizing area is achieved using four bits weighted 2^7, 2^6, 2^5, 2^4. Using these four bits, linearizing corrections between 0.8% and 11.8% of full scale can be applied.

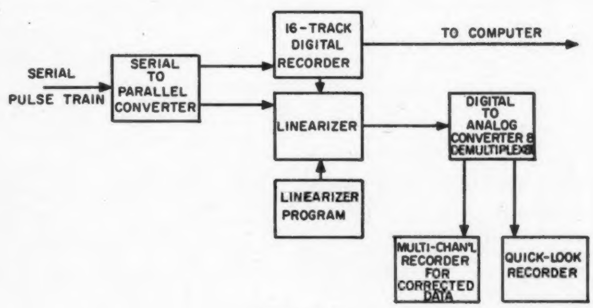

Figure 8

If the calibration curves are divided into sections or zones as shown in Figure 9, a linearizing coefficient can be stored in the linearizer memory for each zone. Whenever a data sample is presented for linearizing, the coefficient to be applied is drawn from the linearizer memory and added to the sample. A convenient number of zones is 16, in which case we have sixteen increments of value 128 ($128 \times 16 = 2048$).

The "address" of a stored linearizing coefficient is conveniently represented by the first four significant bits of an eleven bit data sample. For example, if a data sample presented for linearizing is binary 10001101010 (decimal 1130), the address of the linearizing coefficient is binary 1000 (zone 8). If the correction to be applied to zone 8 is 10% of full scale, the linearizing coefficient should be 204.7. The nearest value to 204.7 which can be obtained from the four bit binary linearizing coefficient is 208 ($2^7 + 2^6 + 2^4$) and this number is added to 1130 to produce the linearized data value of 1338. eg

10001101010	=	1130
1101	=	208
10100111010	=	1338

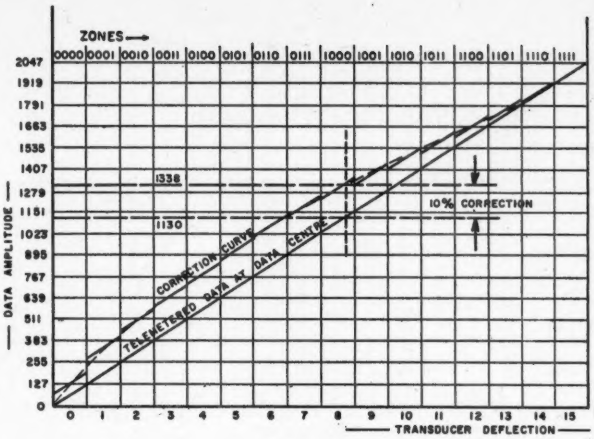

Figure 9

The computation is simple parallel addition which can be carried out on each sample in a word time, thus achieving real-time data linearizing. Scaling can be achieved by adjusting amplifier gain.

A negligible error remains, as a correction coefficient is constant over the range of a zone. This error is directly proportional to the difference in slope between the true and measured data, as indicated by the calibration, the distance between the point of sampling from the centre of a zone and also the number of zones (Figure 10).

Digital recording

The sixteen bit data words arrive at the digital magnetic tape recorder, which we will now refer to as the Primary Recorder, at the word rate of 31,250 words per second. Thus 31,250 binary bits are to be recorded every second on each of the 16 magnetic tape tracks. A practical pulse packing density for a high grade tape may be about 400 bits per inch. With a tape speed of 75 inches

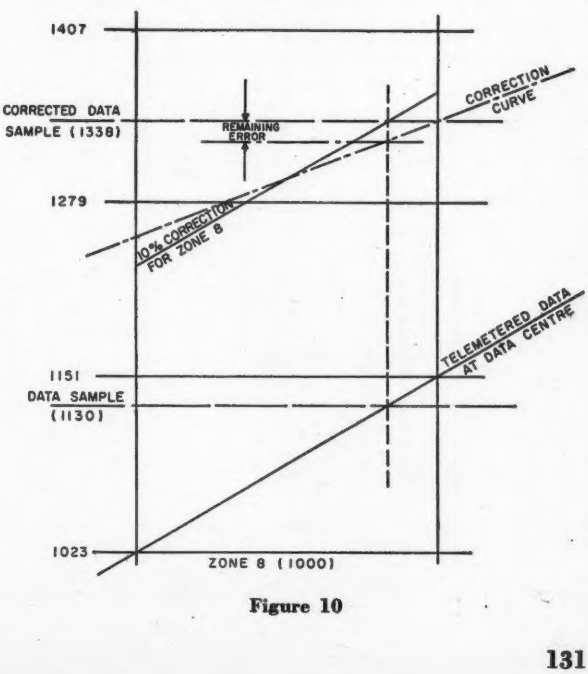

Figure 10

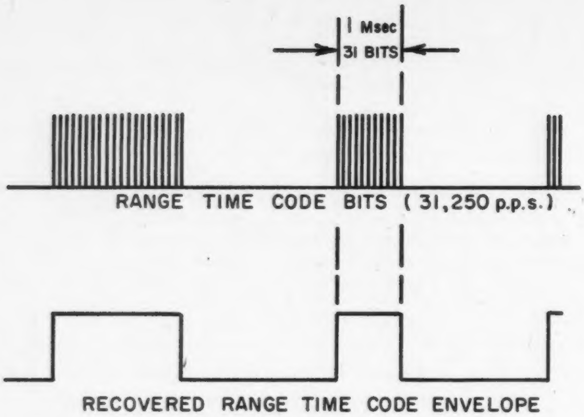

Figure 11

per second, our system will pack about 420 bits per inch, and with standard 10½ inch reels of 3,600 inch tape, 48 seconds of data may be continuously recorded. This is ample for any missile test, but this time can be extended indefinitely using two interchangeable recorders.

It should be noted here that, as editing from the primary recorder will involve the range time signal, one bit has been allotted to each sixteen bit word to convey range time. This one bit is all that is necessary, as it recurs at the word rate of 31,250 words per second. Therefore, a serial pulse train of range time bits will be recorded on one recorder track. The range time code signal will probably only involve 100 pulses per second, the minimum pulse width, likely to be used, being 1 millisecond. If the range time bits are arranged to form the range time code envelope, there will be 31 bits to describe this one millisecond pulse as shown in Figure 11.

It is now necessary to design logic which will extract data from the primary tape, when the period of range time for which information is required is set up. Toggle switches or push buttons can be installed to set up start and stop range times during editing operations. This is much more rapid than reading data from graphical records.

Data may be read directly from the primary tape onto the graphical recorder through the linearizer for fast data reduction, or onto a secondary magnetic tape, punched paper tape, or computer cards. The type of circuitry adopted here depends on choice of digital computer and digital tabulator.

The final system should therefore be in the form shown in Figure 12.

REFERENCE

(1) Nichols, N. H., and Ranch, L. L. — Radio Telemetry, Second Edition, John Wiley & Sons Inc., New York.

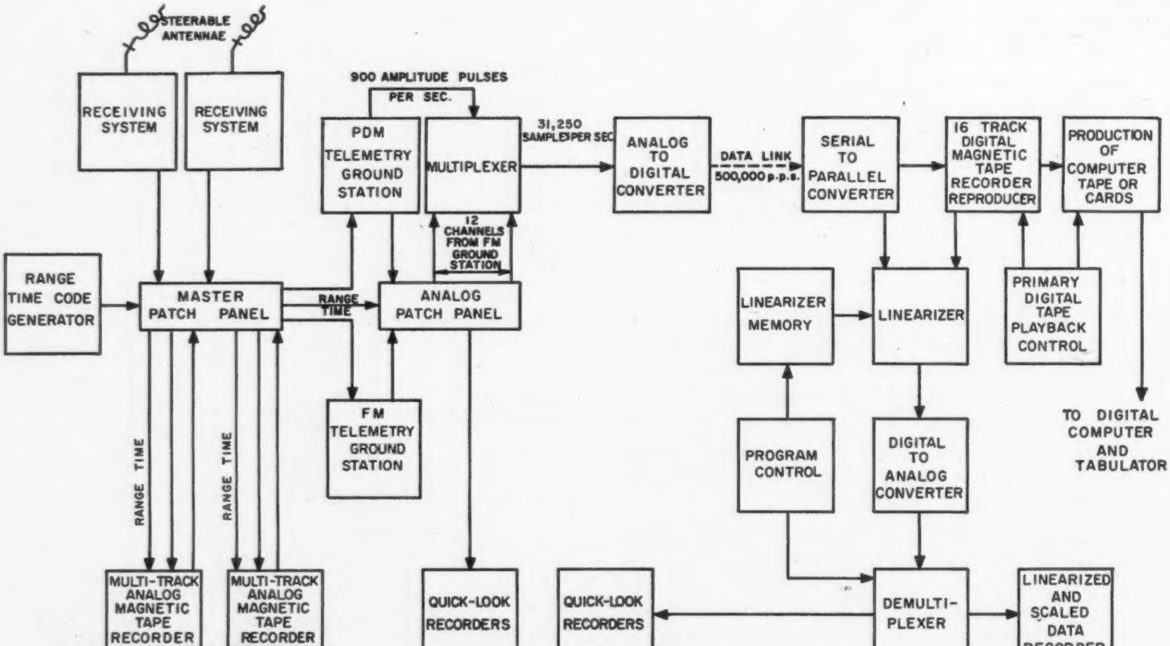

Figure 12

STRESS WAVES†

by Dr. H. F. L. Pinkney*

National Aeronautical Establishment

Just as light, electricity and sound are propagated in our everyday world, stress is propagated through solids. This propagation of stress through solids is well known to seismologists since the understanding of the relationship of the velocities of propagation and related problems of reflection and refraction at surfaces of discontinuity are necessary for the interpretation of seismic records. To the structural engineer, however, or even the dynamic stress analyst, the phenomena may not be too familiar. The lack of familiarity is possibly due to the fact that many problems are static or else, in the case of dynamic loads, the rate of loading in relation to the structure is such that a sum of the first few normal modes yields suitable answers for the domains of interest. The use of normal modes perhaps obscures in one's mind the concept of propagation of stress since, for each mode, stress is distributed throughout the entire structure, and only the sum involving the time-dependent terms provides the constructive and destructive interference patterns which show the propagation. The advantage of normal modes, of course, is that structural discontinuities and boundary conditions are contained in the solution for all time (the accuracy depending on the method), whereas, for the time involved, analysis based on following the propagated stress patterns would involve so many complicated reflections that a solution would be impossible.

There are instances, however, as in the case of uniform rods, where consideration of a dynamic load or impact using stress waves is useful. In particular, with the improvement of electronic, photographic and optical equipment, experiments in stress wave propagation on a laboratory scale are now possible. It is with regard to this use in the laboratory that the understanding and interpretation of stress waves has merit.

The present article is written to familiarize the reader with a few basic concepts of stress waves. The two types of waves, dilatational and distortional, which are propagated in an elastic medium, are discussed. The reflection of these waves at a free boundary is considered and some problems pertinent to seismology indicated. The elementary solutions for longitudinal and torsional waves in rods are derived and the problems, a suddenly applied axial force and longitudinal impact, are treated. Some uses of stress waves, such as determining explosive and impact force-time curves and measuring the physical properties of materials, are indicated.

WAVES IN AN ELASTIC ISOTROPIC MEDIUM

For an elastic isotropic medium, Hooke's law determining the relationship between stress and strain contains only two independent physical constants. These constants, recognizable to the engineer as Young's modulus E and Poisson's ratio ν, are most often used in the form of Lamé's constants, λ and μ. λ and μ in terms of E and ν are as follows:

$$\lambda = \frac{\nu E}{(1+\nu)(1-2\nu)} \qquad \mu = \frac{E}{2(1+\nu)} \tag{1}$$

It is seen that μ is the modulus of rigidity, which, in engineering, is often called G.

The propagation of a disturbance in an elastic isotropic medium is governed by the equations of motion. The equations of motion are derived from the equations of equilibrium using Hooke's law and the strain-displacement relations. For example, in the rectangular coordinates x, y, z where u, v, w are the displacement components in the x, y, z directions respectively, the derived equations of motion[1] are:

$$\begin{aligned}(\lambda+\mu)\frac{\partial}{\partial x}\Delta + \mu\nabla^2 u &= \rho\frac{\partial^2 u}{\partial t^2}\\ (\lambda+\mu)\frac{\partial}{\partial y}\Delta + \mu\nabla^2 v &= \rho\frac{\partial^2 v}{\partial t^2}\\ (\lambda+\mu)\frac{\partial}{\partial z}\Delta + \mu\nabla^2 w &= \rho\frac{\partial^2 w}{\partial t^2}\end{aligned} \tag{2}$$

where

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} = \text{Laplacian operator}$$

ρ = density

$$\Delta = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} \text{ is the dilatation.}$$

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†Paper extracted from the Quarterly Bulletin of the Division of Mechanical Engineering and the National Aeronautical Establishment, July to September, 1959 (DME/NAE 1959(3)).
*Assistant Research Officer

From these equations it can be shown[1, 2, 3] that only two types of waves are propagated and any general disturbance is given by their superposition. Each of these two types of waves, dilatational and distortional, propagates with its own characteristic velocity. Dilatational waves, more properly called irrotational, propagate with the velocity $c_1 = \sqrt{\lambda + 2\mu/\rho}$, and it can be shown that for a plane wave the displacements are *parallel* to the direction of propagation. Distortional waves, more properly called equivoluminal, propagate with the velocity $c_2 = \sqrt{\mu/\rho}$, and it can be shown that for a plane wave the displacements are *transverse* to the direction of propagation.

It is seen, therefore, that these waves not only have distinctly different velocities of propagation but also have distinctly different particle motions associated with them. In the interior of an infinite body they remain separate and distinct for all time. Bodies are not infinite, however, and it is appropriate therefore to consider what happens at a free surface.

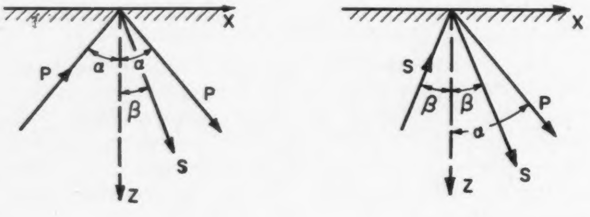

Figure 1
Reflection of elastic waves at a free surface

REFLECTION OF ELASTIC WAVES AT A FREE SURFACE

In general, when either a dilatational or distortional wave is incident on a stress free boundary, reflected waves of both types are required to satisfy the condition of zero stress. Consider the plane free surface, $z = 0$, shown in Figure 1. A plane dilatational wave, termed a P wave in seismology, is incident to the surface at an angle α with the normal (Figure 1a). To satisfy the condition of zero stress ($\sigma_z = \tau_{xz} = \tau_{yz} = 0$) a reflected P wave is required together with a reflected distortional wave (termed an S wave in seismology). The angle of reflection for the P wave is α and the angle of reflection for the S wave is β, where

$$\frac{\sin \alpha}{\sin \beta} = \frac{c_1}{c_2}$$

a law similar to Snell's law in optics. The motion (displacement) in the S wave is transverse to the direction of propagation and lies in a plane normal to the boundary. If the boundary were horizontal, this motion would lie in a vertical plane and the S wave might be referred to as an SV wave.

For a distortional wave incident at an angle β (Figure 1b), a reflected S wave together with a reflected P wave are required. The requirement of the reflected P wave depends only on the component of the incident S wave having displacements in a plane normal to the boundary. If the incident S wave only has motions parallel to the surface, then only a reflected S wave is required whose motions are also parallel to the surface. For a horizontal surface these would be referred to as SH waves.

The magnitude and phase of the reflected waves in relation to the incident wave are determined by the boundary equations satisfying the condition of zero stress. For normal incidence only a reflected normal wave of the same type occurs.

It is to be noticed from the sine law relation that for most materials, $c_1 > c_2$, an incident S wave has a maximum value of β for which values of α for the reflected P wave exist. This angle is a critical angle of incidence.

Problems in grazing incidence and also reflection and refraction at an interface between two different media are likewise similar to the problems in optics.

SOME TYPICAL PROBLEMS IN WAVE PROPAGATION

The problems involved in the treatment of localized disturbances and time dependent boundary forces are usually of extreme mathematical complexity. In many instances, solutions to the equations of motion are sought which give a propagating wave which satisfies the boundary conditions. Some solutions of this type are Rayleigh waves on the surface of a body, longitudinal, torsional and flexural waves in rods, longitudinal and flexural waves in plates, and waves in a layered media. It is appropriate to consider two of these solutions which are important in seismology.

A solution for a plane wave propagating along the plane surface of a semi-infinite solid was first derived by Lord Rayleigh[4]. The disturbance of these waves, Rayleigh waves, decreases rapidly with distance into the solid and therefore they are surface waves. The velocity of propagation, c_R, less than c_2, is independent of frequency. A Rayleigh pulse, consequently, propagates without change of form. Since this wave diverges in two dimensions only, it is of importance in earthquakes and the impact of solids.

Another solution of importance was obtained by Lamb[5] for the case of a localized normal force, an impulse, on the plane surface of a semi-infinite solid. He determined the surface displacements at a large distance from the origin and found that the disturbance consisted of a minor tremor propagating with velocities ranging from c_2 to c_1 followed by a main shock propagating with the Rayleigh velocity c_R. At a large distance, the main shock (Rayleigh waves), separating from the minor tremor, becomes the dominant part of the motion.

Many other problems of this type, in particular those of seismological importance, are discussed in Reference 3. This book, besides the broad treatment given to the various subjects, contains a very extensive bibliography, both with regard to theoretical and experimental investigations.

The theoretical treatment of these problems requires a knowledge of partial differential equations, vector calculus, complex variables and Fourier transform theory. It is not appropriate, therefore, to present any detailed discussion of these problems in the present article. Without becoming too mathematical, however, it is possible

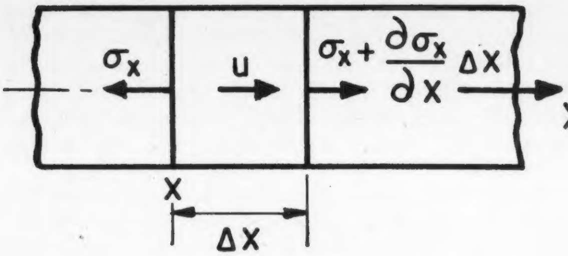

Figure 2
Longitudinal stress on an element of an elastic bar

to discuss the propagation of longitudinal and torsional waves in bars and to consider, in a somewhat physical manner, some problems of engineering interest.

LONGITUDINAL WAVES IN BARS

Consider a uniform bar of cross-sectional area A (Figure 2). Assuming that the longitudinal stress σ_x is uniform over the face of the cross-section and that these faces remain plane, the equation of equilibrium of a segment Δx is

$$A \frac{\partial \sigma_x}{\partial x} \Delta x = A\rho \frac{\partial^2 u}{\partial t^2} \Delta x \tag{3}$$

where ρ is the density and u is the particle displacement in the x-direction.

From the relation for longitudinal stress and strain, viz.,

$$\sigma_x = E\,\epsilon_x = E \frac{\partial u}{\partial x}$$

Eq. (3) may be written as

$$\frac{\partial^2 u}{\partial x^2} = \frac{1}{c_0^2} \frac{\partial^2 u}{\partial t^2} \tag{4}$$

where $c_o = \sqrt{E/\rho}$ is the velocity of propagation (sometimes called the bar velocity). For steel, $c_o = 16{,}800$ ft/sec.

Eq. (4) is the wave equation. It has the general solution.

$$u = F(c_o t - x) + f(c_o t + x) \tag{5}$$

This solution shows that an arbitrarily shaped pulse is propagated along the bar at velocity c_o without change of shape or amplitude.

In practice, the elementary Eq. (4) and solution (5) are found to be valid so long as the length of the pulse is at least several times larger than the lateral dimensions of the bar. When, however, the pulse length is of the order of the lateral dimensions the shape changes with propagation due to dispersion. This dispersion is not included in the elementary solution because of the assumption that the cross-sections remain plane and the stress is uniform over the cross-section. For long wavelengths this assumption is essentially valid, but for short wavelengths (high frequency motion) the lateral inertia which has been neglected becomes important, the cross-section does not remain plane, and the stress is not uniform over the cross-section.

It is sufficient for the present to restrict our attention to the cases where solution (5) is essentially valid. For a wave propagating in the positive x-direction,

$$u = F(c_o t - x)$$

Thus,

$$\dot{u} = \frac{\partial u}{\partial t} = \text{particle velocity} = c_o F'$$

where $'$ denotes differentiation of F with respect to its argument. Similarly,

$$\sigma_x = E \frac{\partial u}{\partial x} = -\,EF'$$

These two relations may be combined to yield a relation between particle velocity and stress as follows:

$$\sigma_x = -\frac{E}{c_o}\dot{u} = -\,\rho c_o \dot{u}$$

or in the usual form as

$$\sigma_x = -\sqrt{E\rho}\,\dot{u} \tag{6}$$

For a wave propagating in the negative x-direction

$$\dot{u} = c_o f'$$

$$\sigma_x = E f'$$

and hence

$$\sigma_x = +\sqrt{E\rho}\,\dot{u} \tag{7}$$

Thus, for a propagating disturbance there is a definite relationship between particle velocity and stress. Relations (6) and (7) show that for a compressive stress the particle velocity is in the direction of propagation, whilst for a tensile stress the velocity is opposite to the direction of propagation.

When a stress wave arrives at the end of a finite rod, the boundary condition, depending on the end fixity, must be satisfied. Consider, for example, the two common types of end fixity, a fixed end and a free end. For the fixed end, $u = 0$, an incident compressive pulse gives rise to a reflected compressive pulse and an incident tensile pulse gives rise to a reflected tensile pulse. For the free end, $\sigma_x = 0$, an incident compressive pulse gives rise to a reflected tensile pulse and vice versa.

Using the elementary solution and relations (6) and (7) it is possible to construct the solutions for a rod acted upon by a suddenly applied axial force, and under the longitudinal impact of a mass.

SUDDENLY APPLIED AXIAL FORCE

A uniformly distributed axial force P is suddenly applied to the end, $x = 0$, of a uniform rod of cross-sectional area A and length l as shown in Figure 3. The initial conditions are, for $t = 0$,

$$u = 0 \qquad 0 \le x \le l$$

$$\dot{u} = 0 \qquad 0 \le x \le l$$

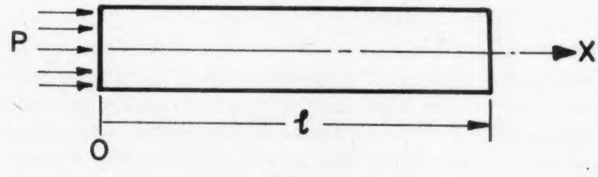

Figure 3
Suddenly applied axial force

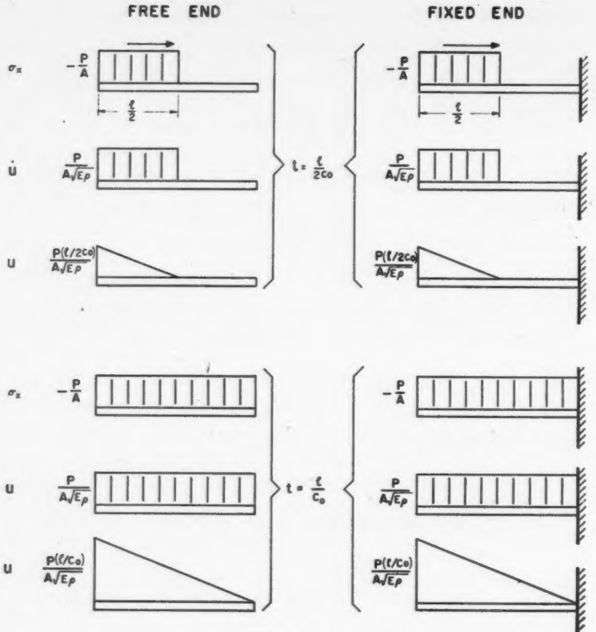

Figure 4

The stress at $x = 0$ is

$$\sigma_x = 0 \qquad \text{for } t \leq 0$$
$$\sigma_x = -P/A \text{ for } t > 0$$

From solution (5), at $x = 0$,

$$\sigma_x = -P/A = -E F'(c_0 t) \text{ for } t > 0$$

It is thus seen that a compressive wave of constant amplitude P/A propagates down the rod in the positive x-direction with the velocity c_0. From relation (6) the particle velocity associated with this stress wave is

$$\dot{u} = \frac{P}{A\sqrt{E\rho}}$$

Up to now, nothing has been said about the end condition at $x = l$. It is only necessary to consider this end fixity at the time when the stress wave has arrived, i.e. $t = l/c_0$. It is informative to consider the two types of end fixity, a free end and a fixed end. The stress, velocity and displacement diagrams are constructed in a simple fashion by following the propagated stress wave and are given in Figures 4, 5 and 6.

It is seen that there is no difference between the two cases up to the time when the stress wave arrives at the end $x = l$. For $t > l/c_0$, the end fixity enters the picture and the two cases begin to differ.

For the free end, the incident compression wave gives rise to a reflected tension wave of equal magnitude which propagates in the negative x-direction. From relation (7) the particle velocity $\dot{u}$ associated with this reflected wave is also of magnitude $P/(A\sqrt{E\rho})$ and is in the positive x-direction. Thus, the superposition of the incident and reflected waves show that the stress cancels while the particle velocity adds. The particle velocity $\dot{u}$ is not to be confused with the velocity of propagation of the stress which is constant (c_0).

For the fixed end, the incident compression wave gives rise to a reflected compression wave. From relation (7) it is seen that now the velocity $\dot{u}$ associated with this reflected wave is in the negative x-direction. Thus, the superposition of the incident and reflected waves shows that the stress adds while the velocity cancels.

At $t = 2l/c_0$, the reflected waves arrive at the end $x = 0$. The condition to be satisfied is $\sigma_x = -P/A$. For the free end rod, the arrival of the reflected tension wave requires a compression wave to be propagated in the positive x-direction. The arrival of the reflected compression wave in the fixed end rod requires a tension wave to be propagated in the positive x-direction.

It is appropriate to consider the stress, velocity and displacement at $t = 2l/c_0$. For the free end rod, the stress is zero (except at the end $x = 0$) and the velocity and displacement are *uniform* along the rod.

Now considering for a moment a rigid rod free to move under the applied force, we would have

$$\ddot{u} = P/(Al\rho)$$

and hence

$$\dot{u} = [P/(Al\rho)]t$$
$$u = (1/2)\,[P/(Al\rho)]t^2$$

Thus, at time $t = 2l/c_0$,

$$\dot{u} = [P/(Al\rho)]\,2l/c_0 = 2P/A\sqrt{E\rho}$$

and

$$u = (1/2)\,[P/(Al\rho)]\,[2l/c_0]^2 = P\,(2l/c_0)/A\sqrt{E\rho}$$

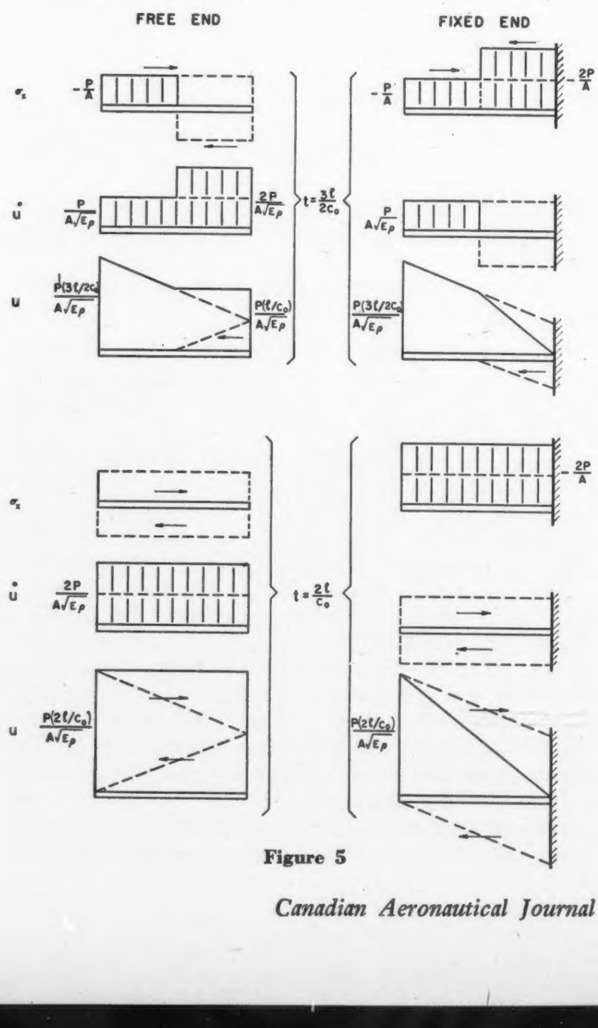

Figure 5

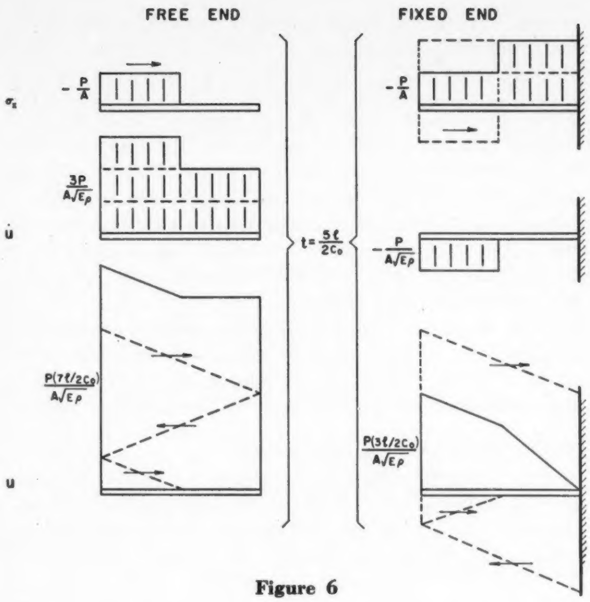

Figure 6

It is seen, therefore, that at time $t = 2l/c_0$, the free end elastic rod has the same velocity and displacement as one deduces by the application of rigid body dynamics.

For the fixed end rod, at time $t = 2l/c_0$, the rod is at rest and the displacement and stress are *twice* the static values. It is seen that this is a maximum since the subsequent tension wave (Figure 6) acts as a wave of unloading. The factor 2 is the value given in the handbooks for a suddenly applied load[6].

The displacement of the loaded end, $x = 0$, of the fixed end rod may be constructed for all time. It is as shown in Figure 7. This figure is to be compared with Figure 32 of Reference 7, where the problem has been treated using Laplace transforms. The use of Laplace transforms in more difficult problems is essential when the actual generation of particular stress wave patterns is not clearly obvious and where the influence of boundaries is important.

LONGITUDINAL IMPACT ON THE END OF A ROD

When a rigid mass M impacts the end of the rod, $x = 0$ (Figure 8), a stress wave is generated. At the instant of impact the mass has velocity V so that instantaneously the particles at the end of the rod are given a velocity V. From relation (6) this means that the stress is

$$\sigma_x = -\sqrt{E\rho}\, V$$

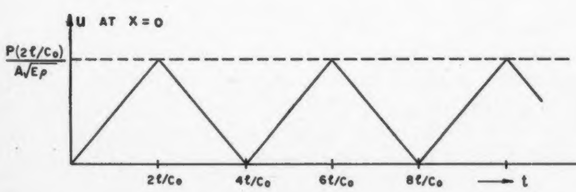

Figure 7
Displacement of the loaded end of the fixed end bar

The cross-sectional area of the rod is A. Writing v for the instantaneous velocity of the mass, then

$$M\frac{dv}{dt} - A\sigma_x = 0 \qquad \text{at } x = 0 \tag{8}$$

Substituting for v from the relation for $\dot{u}$ and σ_x (relation (6)), then

$$\frac{M}{A\sqrt{E\rho}}\frac{d\sigma_x}{dt} + \sigma_x = 0$$

from which

$$\sigma_x = -\sqrt{E\rho}\, Ve^{-\frac{A\sqrt{E\rho}}{M}t} \qquad \text{at } x = 0 \tag{9}$$

This relation applies until $t = 2l/c_0$, at which time the front of the stress wave, reflected at the fixed end, arrives back at the impact end. Since the velocity of the mass cannot change suddenly, this wave is reflected as from a fixed end, and the stress at this impact end suddenly increases by $-2\sqrt{E\rho}\, V$. An increase in stress of this type occurs at every interval of time, $2l/c_0$. The stress at the impact end is composed of the superposition of the wave propagating down the bar and the arrival of the previous wave which has been reflected at the fixed end.

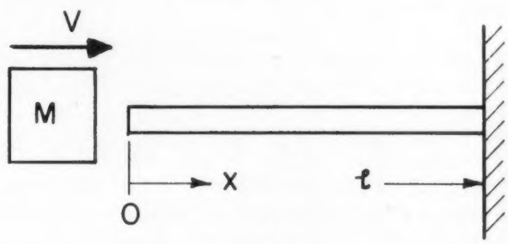

Figure 8
Longitudinal impact on end of rod

After the n[th] arrival at the impact end, the stress is

$$\sigma_x = \sigma_{xn}(t) + \sigma_{x(n-1)}(t - 2l/c_0) \tag{10}$$

where $\sigma_{xn}(t)$ is the stress for the wave propagating along the rod and $\sigma_{x(n-1)}(t - 2l/c_0)$ is the stress in the returning wave from the fixed end.

From relations (6) and (7) the velocity of the mass is

$$v = \frac{1}{\sqrt{E\rho}}[-\sigma_{xn}(t) + \sigma_{x(n-1)}(t - 2l/c_0)] \tag{11}$$

The substitution of (10) and (11) in (8) gives the differential equation for determining $\sigma_{xn}(t)$ in terms of $\sigma_{x(n-1)}$. Of course, Eq. (9) is the solution of σ_{x0}. Proceeding to $\sigma_{x1}, \sigma_{x2}, \ldots$ the stress in the bar is obtained for the time up to the end of impact. The impact is over when the stress at the impact end becomes tensile. A detailed account of this impact on the end of a rod is given in Reference 2. The important aspect to be observed is that the initial magnitude of the stress does not depend on the kinetic energy or momentum of the mass but only on its velocity. Thus, for a very light mass in relation to the rod, although the kinetic energy and momentum may be small, the peak stress, occurring at the fixed end,

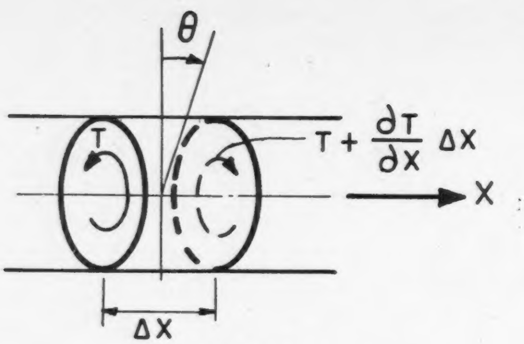

Figure 9
Torque applied to an element of a cylindrical rod

may be very large. As a comparison, for $M/l\rho A = 1$, it is shown in Reference 2 that the peak stress at the fixed end is

$$\sigma_x = -2.270\sqrt{E\rho}\,V$$

which occurs at the time of the second arrival (i.e. $t = 3l/c_o$). Based on a calculation which assumes that the kinetic energy is equal to the *uniformly* distributed strain energy in the rod, the stress obtained is

$$\sigma_x = -\sqrt{E\rho}\,V$$

This value is that given in handbooks for the calculation of stress under impact[6]. It is seen that the value is low by more than 50%, and this discrepancy increases for decreasing values of $M/l\rho A$. Of course, in many cases, $M/l\rho A$ is very large and the discrepancy becomes small.

TORSIONAL WAVES IN RODS

Consider a cylindrical rod of radius a (Figure 9). Let the torque at x be T and the opposing torque at $x + \Delta x$ be $T + (\partial T/\partial x)\,\Delta x$. If the mean angle of rotation of the element Δx about its centre is θ, then the equation of equilibrium is

$$\frac{\partial T}{\partial x}\Delta x = I_p'\frac{\partial^2\theta}{\partial t^2} \tag{12}$$

where I_p' is the moment of inertia of the element about the x-axis.

It can be shown that for the cylindrical rod,

$$T = \frac{\pi}{2}\mu a^4\frac{\partial\theta}{\partial x} \tag{13}$$

and

$$I_p' = \frac{\pi}{2}\rho a^4\,\Delta x \tag{14}$$

The substitution of (13) and (14) in Eq. (12) yields

$$\mu\frac{\partial^2\theta}{\partial x^2} = \rho\frac{\partial^2\theta}{\partial t^2} \tag{15}$$

which may be written as

$$\frac{\partial^2\theta}{\partial x^2} = \frac{1}{c_2^2}\frac{\partial^2\theta}{\partial t^2} \tag{16}$$

where $c_2 = \sqrt{\mu/\rho}$ is the velocity of propagation of distortional waves in an infinite medium.

Eq. (16) is the wave equation. Similar to Eq. (4) it has the general solution

$$\theta = H(c_2 t - x) + h(c_2 t + x) \tag{17}$$

Thus, a torsional pulse is propagated along the rod without change of shape or amplitude. Unlike the case of longitudinal waves (solution (5)), solution (17) for torsional waves applies for all frequencies and hence very short pulses, since the fundamental torsion mode for a circular rod, obtained using the equations of motion, has each cross-section rotating as a whole about the longitudinal axis (x-axis).

The solutions for a suddenly applied torque and rotational impact at the end of a rod could be constructed in an analogous manner to the previous cases of a suddenly applied axial force and longitudinal impact.

TRANSVERSE IMPACT OF CABLES

The transverse impact of cables is a problem of engineering significance because of its importance in arresting gear. In a manner analogous to the longitudinal impact, the transverse impact on a cable generates a tension wave whose initial amplitude depends on the velocity of impact and not on the mass of the object being arrested. When the cable is impacted (Figure 10) the centre moves and the cable is essentially as shown in Figure 10a. We have what is known as a "kinking wave" which moves outward as shown in Figures 10b, c, d and e. The author of Reference 8 has considered the theoretical aspects of the problem and has derived relations for the stress in the cable not only for transverse impacts but also for oblique impacts. He gives a comparison of the theoretical stress with the measured stress in aircraft arresting gears with cables of ⅞, 1 and 1⅜ inches in diameter.

If the mass is large enough that several transverses of the tension wave occur in the cable, the maximum velocity of arrest may be unnecessarily limited. Such a

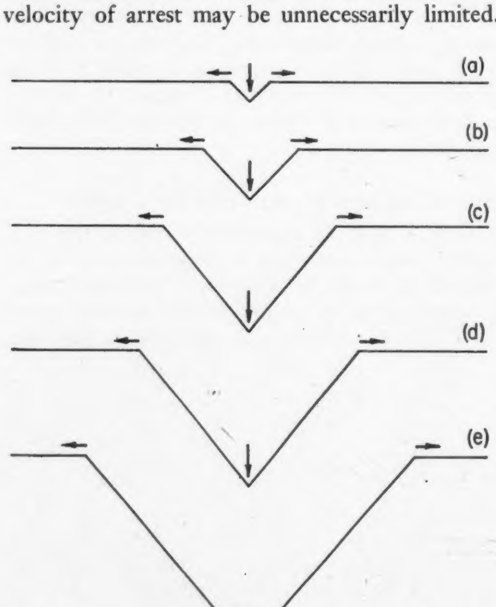

Figure 10
Motion of a cable under transverse impact

problem was investigated by the authors of Reference 9, who, by means of suitable dampers at the anchored ends of the cable, were able to suppress these tension waves and increased the maximum velocity of arrest, for a typical arresting gear, from 120 knots to 150 knots.

USES OF STRESS WAVES

The knowledge of stress waves permits their use in non-destructive testing. In particular, longitudinal waves in rods find application for measuring explosive and impact force-time curves. The first such application was made by B. Hopkinson[10] who set up the now famous Hopkinson pressure bar. At one end of a cylindrical rod, approximately 1 inch diameter and several feet long, a small amount of explosive was fired or a bullet was impacted. At the other end of the rod a time-piece was slid on the bar, the cross-section and the material of the time-piece being the same as the rod. The compression pulse, generated by the explosion or impact, propagated down the rod, into the time-piece and was reflected at the free end as a tension pulse. When the superposition of the compression pulse and the reflected tension pulse yielded a tensile stress at the joining of the time-piece and the rod, the time-piece flew off and was caught in a ballistic pendulum. The minimum length of time-piece was found which left the rod stationary. This length of time-piece contained the total momentum in the pulse and was approximately one-half the pulse length. Using this momentum and length of pulse, a value for the peak force was obtained. The results, however, did not permit the actual shape of the force-time curve to be determined.

With the advent of improved oscilloscopes and photographic equipment, Davies[11] modified the Hopkinson pressure bar. Instead of a time-piece, he used an arrangement where the end of the rod formed one plate of a parallel condenser. The condenser was charged and any motion of the end of the rod changed the gap, and hence the capacitance, which resulted in a change of voltage. For small motions, the voltage was linearly related to the displacement. Recording this voltage, together with a time base voltage, yielded the displacement-time curve for the end of the rod. The stress-time curve of the impact (or explosion) was determined by the differentiation of this curve.

Another method also used by Davies was a cylindrical condenser which measured the radial displacement of the rod associated with the pulse. The radial displacement is related to the axial stress through the relation

$$u_r = \frac{\nu a}{E} \sigma_x$$

Thus, the voltage recorded is directly related to the stress without a differentiation being required.

The use of longitudinal waves is limited to pulses longer than the diameter of the bar. When the pulses become shorter, the effects of dispersion are such that the recorded end displacement is no longer the form of the original pulse which started down the bar.

It has been shown that torsional waves, in the fundamental mode, are not affected by dispersion. Thus, if instead of using the explosion or impact to excite a longitudinal pulse, rather they are used to excite a torsional pulse, the effect of dispersion can be avoided. Using such a torsional mechanism, Davies and Owen[1] satisfactorily recorded large amplitude pulses whose durations were less than one microsecond.

The use of stress waves as applied to pressure bars depends on the stresses being less than the yield stress of the bar. Of course the yield stress may be strain-rate sensitive. Thus, a value recorded above the static yield stress might be valid since it may still be less than the dynamic yield stress for the recorded pulse rate.

Another use of stress waves, particularly applicable to non-dispersive media, is to measure the elastic properties of materials. Since the velocities of propagation depend on the elastic constants, the measurement of longitudinal and torsional waves permits the determination of E and ν.

A modification of the pressure bar (see Reference 1) is to have it in two sections at the recording end. Between these two sections a thin disk of another material, plastic or rubber, is inserted. A cylindrical condenser records the initial pulse propagated down the bar towards the specimen. A parallel condenser on the end of the second section of the bar records the pulse transmitted through the specimen. The appropriate use of these two records permits the determination of the stress-strain relation for the material of the disk when taken through a large amplitude stress cycle of the order of duration of tens of microseconds.

When the amplitude of the pulse exceeds the elastic limit we have elastic waves followed by a plastic wave. Since superposition no longer applies, the stress wave pattern, following reflections and unloading, can become very complicated. The theoretical treatment of non-linear elastic materials and the dynamic failure of materials involves some understanding of such plastic waves. In carrying out tests on the failure of materials at high rates of loading[14] the specimen, because of these stress waves, may not be uniformly strained over the measured gauge length, and also, the usual methods of measuring load will not apply owing to the inertia forces. Thus, high speed tests, in which appropriate consideration has not been given to eliminate or measure these effects, will yield results not pertinent to the material of the specimen, but rather pertinent only to the specimen in the particular testing machine used in the test.

For transparent materials, photoelastic techniques using high speed photography are very useful. The photographs provide a visual record of the propagated stress waves. They can show, for example, the propagated stress waves from a small explosion on the edge of a finite plate and the pattern of the reflected tensile waves from the free boundaries which cause various patterns of failure.

The increasing military importance of the knowledge of stress waves has given rise to quite a large number of recent papers dealing with various types of problems. Two recent publications, "Experimental Wave-Propagation in Solids" by H. Kolsky[16] and "Impact Physics" by R. Graham[17] give extensive bibliographies of the recent work which has been done. The interested reader and the engineer involved with stress wave problems will find them to be very useful reference sources.

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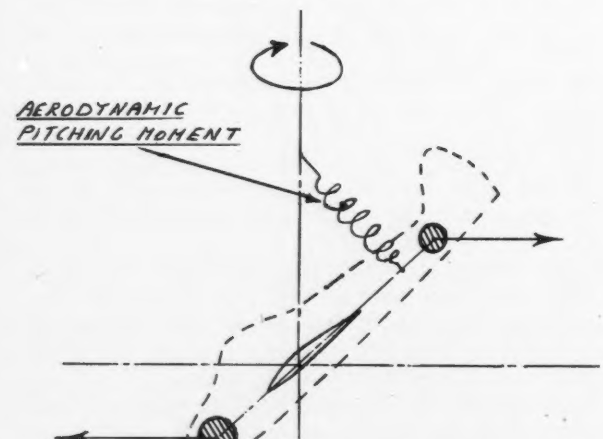
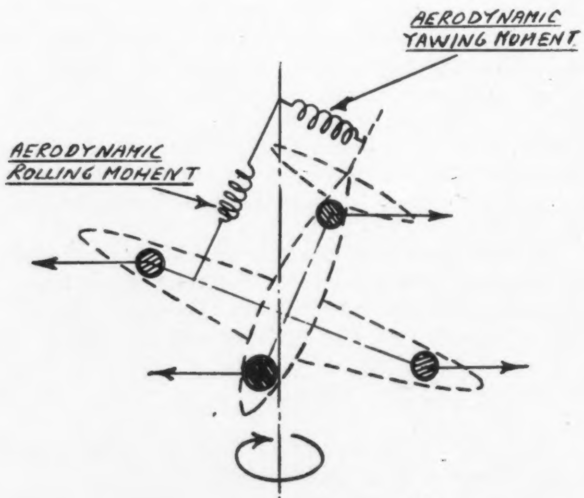
TECHNICAL FORUM

CANADAIR CL-41





On page 42 of the February issue, a statement was made to the effect that a high horizontal tailplane gives effective rudder for recovery from a normal spin.

Surely the reverse is true for an inverted spin.

The statement "In many aircraft the distribution of fuel in the wing results in marginal spin and recovery characteristics" could be misleading. Distribution of mass in the wings is in itself a desirable spin feature (see Figures). In the particular case of fuel loading, discrepancies arise due to the fact that spinning characteristics changes as fuel is used regardless of asymmetry.

Santa Monica, California R. M. SELLENS

C.A.I. LOG

SECRETARY'S LETTER

MID-SEASON MEETING

In this issue we report in full on the Mid-season Meeting. After all the upheavals of 1959, the Special Anniversary Meeting in February, the Annual General Meeting in remote Cape Breton in June, the Anglo-American Conference and, by no means least, the Arrow-Iroquois disaster – after all these, the Mid-season Meeting was the first function in our return to our ordinary routine and it proved to be an auspicious one. It was the best-attended Mid-season Meeting we have had and, in my opinion, its programme was excellent.

The Edmonton Branch is to be particularly congratulated for the arrangements they had made and for the way their Committee rallied round to make sure that everything clicked.

QUEBEC

A tenth Branch has been added to the family, Quebec. I was invited to attend a meeting there on the 3rd March and a very interesting meeting it proved to be. It was held in the Talon Vaults – Les Voûtes Jean Talon – a most appropriate place for the birth of a Branch in that historic city. Jean Talon was the first intendant of New France, appointed in 1665, and, though I believe he blotted his copybook later, he established the first brewery in Canada and left these vaults as a worthy memorial. I should explain that a part of the vaults has been converted into a very pleasant lounge and it was here, by courtesy of the Dow Brewery, that the meeting took place.

I think it unlikely that the Quebec Branch will ever become a very big one in terms of membership, but I feel sure that it will be stable and will be able to contribute significantly to the Institute's over-all programme. At present CARDE provides the backbone of the Branch, but it is by no means the only aeronautical activity in the district and I hope that, in particular, Laval University will play an active role in due course.

MONTREAL

The President and I had intended to visit Montreal for their Branch meeting on the 16th March but unfortunately at the last moment the President went sick and I had to make the trip alone. It was a dinner meeting, as is the Montreal custom. Their plan is to begin with a dinner, attended by those who will, and this is followed by the technical session, for which a lot of other members turn up. Between the dinner and the session, there is a break during which the dinner is completely cleared away; this is a good arrangement, because it removes all "after dinner" evidence from the technical part of the meeting.

The Montreal Branch Executive Committee is inclined to worry about the attendance at their meetings but certainly there was quite a good attendance on this occasion, for the technical session at any rate. What was more important, it was a keen and interested attendance; I was considerably encouraged, and the more sorry that the President had missed a good meeting.

Another visitor, besides myself, was F/L Weinstein, Chairman of the Edmonton Branch. He had apparently recovered from his exertions at the Mid-season Meeting and I am sure that, with me, he enjoyed relaxing and letting somebody else run the show.

As I have said before it is difficult to resist listing the many friends I meet when I make these visits to Branches – and no doubt many of their friends in other Branches would like to hear of them. But I must content myself with thanking Mr. R. F. O. Smith, the Branch Chairman, for a very pleasant evening.

NEW YORK

Two days after visiting Montreal I paid a flying visit to IAS Headquarters in New York. I had a number of things to discuss with Mr. Dexter and they had been building up for some time. Although it is easy and natural to assume that, with the passage of years and our growing independence, the IAS is no longer interested in the CAI, this is not the case at all. They have a very close interest in us and are extremely well informed on our progress and our troubles. (They must read the Journal from cover to cover; I even suspect them of reading between the lines.)

For once I was lucky to find most of their Headquarters staff at home; for they travel a good deal. Everybody was most helpful and, although my visit was a short one, I came away with all the advice I was after and a good understanding of IAS thinking on a number of common problems.

MID-SEASON MEETING

The Mid-season Meeting of the Institute was held in Edmonton on the 19th and 20th February, a Friday and Saturday. The programme proved to be extremely good and the attendance was a good deal higher than had been expected.

A total registration of 161 included 115 from outside the Edmonton district; it was particularly gratifying to see 39 Students from the Provincial Institute of Technology and Art, come from Calgary for the occasion. All the technical sessions, except one, were almost uncomfortably crowded. The exception was the Electronics Session on the Friday evening, which was attended by only 35 people; this can probably be accounted for by the fact that Friday evenings have other attractions and by the chronic and lamentable indifference of aeronautical engineers to this basic subject; anyway those who stayed away missed one of the highlights of the meeting.

F/L K. Weinstein, the Chairman of the Edmonton Branch, opened the proceedings at the beginning of the Friday morning session, with a short speech of welcome. He had reason to be proud of the preparations made by his Branch; one very interesting feature of the Meeting was an exhibition of photographs of the early days of flying in the Edmonton area, which was set up with great effect in the main lobby of the hotel.

The technical sessions are reported below.

The President speaking at the Dinner
(l to r) F/L K. Weinstein, Chairman, Edmonton Branch; Mr. R. G. Robertson, Principal Speaker; Dr. D. C. MacPhail, President, CAI; Mr. D. Boyd, Vice-President, CAI, and Mr. B. W. Pitfield, Vice-President and General Manager of Northwest Industries

THE DINNER

The concluding event was the Dinner, held in the Lower Main Banquet Room of the hotel and attended by 145 members and guests. The head table included members of the Council from seven Branches, Mr. B. W. Pitfield, Vice-President and General Manager of Northwest Industries Ltd., the Honourable George Prudham, representing the City of Edmonton, and, of course, the Principal Speaker, Mr. R. G. Robertson, Deputy Minister of Northern Affairs and National Resources. Under the recently adopted revision of the constitution of the Council, the President and Vice-President for 1960-61 had been elected at a meeting of the Council held immediately before the Meeting, on the 18th February, and, in introducing the head table guests, the President referred to Mr. D. Boyd as the President-elect and to A/C W. P. Gouin as the Vice-President-elect, initiating an announcement which is likely to become traditional at Mid-season Meetings of the Institute.

In his address the President reminded his audience that it was a year to the day (the 20th February) since the cancellation of the Arrow, which had been, for Canada, the first impact of the storm which was sweeping the aeronautical world. The Institute had reefed in its budget and things were already beginning to look brighter. Referring to the tour of the western Branches which he had made with the Secretary in January, he said that he had been most heartened by the ingenuity and vitality displayed by all the Branches in what had been a difficult year. But he criticized the Branches for failing to recognize and develop the talents hidden in the membership of each of them, and recommended a strengthening of inter-Branch relationships by the exchange of speakers from among their own members.

He said that the programme of the present meeting had been typical of the Council's planning for the months ahead and its obvious success was very encouraging. Stress would be laid upon the engineering and economic problems of air transport in all its phases, but the Institute would steadily increase its activity in the new fields of space flight; it was hoped to extend the membership of the Astronautics Section to the west. He briefly described the programme planned for the Annual General Meeting in May, which, while including one session on astronautics, would be chiefly devoted to transport, air freight and the industrial side of aviation. The Turnbull Lecture, which would be delivered at the Annual General Meeting by Mr. A. E. Raymond of Douglas, would be concerned with the development of jet transport — a very timely and appropriate subject.

Mr. R. G. Robertson, the Principal Speaker

Finally he introduced the Principal Speaker, Mr. R. G. Robertson, whose address he described as the climax of the present programme and bridge to the next.

Mr. Robertson's address is published in full on pages 116 to 118 of this issue. In brief he said that the problems of northern development were primarily economic and their solution dependent very largely on flexible and cheap transportation. The Northwest Territories and the Yukon represent some 40% of the area of Canada and this consideration gives some scale to the magnitude of the transport requirements. He challenged the aviation industry to meet them. It was an extremely stimulating talk and most suitable to the occasion.

F/L Weinstein was asked by the President to move a vote of thanks. In a delightful and witty manner, he gave a spurious explanation of the reason for his wearing his arm in a sling (in fact he had a painfully poisoned finger), thanked Mr. Robertson for an address so fitting to the "Gateway to the North", thanked all those members who had come from afar to attend the Meeting and thanked the members of his Branch who had worked so hard to make it a success. He explained that he felt it necessary to say a little more than the South African farmer whom, in similar circumstances, he had once heard discharge his duties with the simple statement "T'anks – T'anks – T'anks".

F/L K. Weinstein, Chairman of the Edmonton Branch, moving the vote of thanks

TECHNICAL SESSIONS

The technical sessions have been reported upon by members of the Edmonton Branch, as follows:

Fuel and Oil Session: (l to r) Mr. J. W. Noonan, Mr. J. P. Perry, Mr. R. G. Davies, and Mr. C. M. Hovey (Chairman)

Morning Session, February 19th
Fuel and Oil

Reported by R. W. Van Horne

The 1960 Mid-season Meeting of the CAI was opened by F/L K. Weinstein, Chairman of the Edmonton Branch, who welcomed the 120 members and guests attending the first session.

Session Chairman, Mr. C. M. Hovey of the Winnipeg Division of Bristol Aero-Industries Ltd., introduced Mr. R. G. Davies, Senior Chemist of Shell Oil Company of Canada Ltd. The topic of Mr. Davies' paper was "Recent Advances in Aircraft Fuels". Mr. Davies dealt with the state of the art regarding piston engine fuel. He then indicated that very little was being done in the way of new developments in this field, due to the emphasis on jet power and the apparent fact that further development in piston power in the high power categories was not likely.

The different specifications of jet fuel were illustrated by means of slides and the relative merits of present jet fuels were compared. Present fuels each have their own advantages, and in light of their applications the aviation industry must weigh all the factors in choosing the best fuel for engine type and operational requirements.

Mr. Davies dealt with the factors of luminosity and smoke point in relation to the performance of jet engines and the best power recovery from them.

Much development work is going on in the field of high energy fuels, such as boron, for rockets and space vehicles. It was made apparent that this class of fuels present their own special problems in handling and storage as well as the design of the vehicle to use them, due to corrosive and other difficult characteristics.

The second paper of the session was delivered by Mr. J. W. Noonan of the National Research Council who spoke on "An Engineering Approach to the Rating of Aircraft Fluid Filters".

By means of slides Mr. Noonan illustrated the approach to the problem of filtering hydraulic fluid in aircraft systems. He also outlined the difficulty in filter design in removing the odd shapes of foreign materials which inevitably find their way into systems either during the filling operation, repair to component parts, or wear in the system itself.

Mr. Noonan dwelt on the development of minute glass beads as a filtering element for the laboratory testing. This approach allowed accurate measurement of particle sizes so that filter efficiencies could be measured.

It is apparent from the amount of laboratory work on the subject carried out at the National Research Council that fluid filtering is an involved problem and that it is assuming even greater significance in modern aircraft.

Mr. J. P. Perry of the Technical Services Branch of Imperial Oil Ltd. presented the final paper of the session on the subject "Synthetic Lubricants in Aircraft Gas Turbines". Mr. Perry dealt with the development of synthetic oils in Great Britain and the United States and illustrated film strengths, pressure factors and other relative merits. The gas turbine oils must operate at much higher temperatures than piston engines, particularly at the hot end; and with the normally smaller amount of oil carried and greater oil flow than the piston engine they must reject a considerable amount of heat without breaking down.

As power outputs increase and even higher lubricating temperatures become a factor in such vehicles as Mach 2 or higher, Mr. Perry felt that "total loss" systems may become necessary.

Mr. Perry was asked about the possibility of synthetic oils in piston engines, and indications were that the higher cost, as compared with conventional oils, made it unlikely, as well as

Astronautics Session (l to r) Mr. W. A. B. Saunders (Chairman), Mr. R. L. Schultz, Mr. D. K. Breaux and Dr. J. L. Locke

a few other problems such as the paint removing capabilities of synthetic oils.

The speakers were warmly thanked by the Chairman, Mr. Hovey, and the meeting broke up for lunch.

Afternoon Session, February 19th
Astronautics

Reported by F/O A. J. Robinson

This Session was chaired by Mr. W. A. B. Saunders, Vice Principal, Provincial Institute of Technology and Art, Calgary.

The session opened with the showing of two films: the first entitled "X minus 80 days" was produced by the US Army Ballistic Missile Agency together with the California Jet Propulsion Laboratory, and showed the preparations made to put the Explorer satellite in orbit in January, 1958, as a US Army IGY project. This excellent colour film showed in detail the problems involved in planning and launching the Jupiter C rocket.

The second film entitled "Widest Horizons" was made by the Rocketdyne Division of North American Aviation and showed the mechanical and physiological problems associated with putting a man in space using the current version of the X-15 and some future planned developments.

The first paper of the afternoon was presented by Dr. J. L. Locke, Officer in charge, Dominion Radio Astrophysical Observatory, Penticton. His lecture entitled "Space Astronomy" showed how rockets and satellites are playing an increasing part in the observations of space using telescopes and spectrographs. Dr. Locke described how visual observations of space from the earth's surface were made difficult by the motions of the atmosphere and by the night light in the sky known as air glow. Similarly, spectrographic observations from the earth are made difficult by the opaqueness of the atmosphere to the spectrum below 3,000 Angstroms. Above 200 kilometers the atmosphere becomes sufficiently clear for accurate measurements to be made.

He described the need for closer observation of the moon's surface and described how this is best done by unmanned space stations in orbit. However telescopes in orbit suffer a severe problem of thermal stress since one side is heated by the sun while the other is cold. Observations of the sun must also be made using satellites as an observation platform.

Dr. Locke concluded his lecture by stressing the need for close approaches to the moon's surface and for much greater study of the Van Allen radiation belt discovered by early satellites.

In the question period which followed the lecture, Dr. Locke explained that the new Dominion Radio Observatory is situated in the mountains near Penticton, B.C. and is presently engaged in research on the emission of galactic hydrogen. He also expressed the opinion that the increasing research being done in space might eventually help solve the general equation of the origin of the universe.

After a vote of thanks for Dr. Locke, the Chairman introduced the second speaker of the Astronautics Session, Mr. D. K. Breaux, Project Engineer, Missile Systems of the AiResearch Manufacturing Company, Division of the Garrett Corporation. Mr. Breaux presented a paper entitled "Non-Propulsive Power Systems for Missiles and Space Vehicles" which he produced in conjunction with Mr. R. L. Schultz, Group Supervisor, Preliminary Design, AiResearch Manufacturing Company. Their lecture described in general terms the design of non-propulsive power systems and their applications.

The two basic systems for conversion of energy were shown: primary and secondary. A primary device was described as a one step process such as a battery, whereas a secondary device uses additional steps to perform the conversion, for example a heat engine. Generally primary systems are used where there is a requirement for low power over a long time while secondary systems are used when high power is required for a shorter period of time.

For an unmanned orbital satellite 1 hp is required in the non-propulsive power system. For a manned re-entry vehicle at least 100 hp are required, the cooling requirement for re-entry being as high as 10^7 Btu/hr.

Non-propulsive power systems are required for such applications as electrical power, cooling, heating etc and because of their low specific fuel consumption hydrogen systems are widely used for installations where power is required for less than one hour. For applications requiring power for more than one hour but less than one month, hydrogen/oxygen systems are better since they require less volume for storage of the fuel. For periods of over one month Mr. Breaux felt that atomic power could be used.

A hydrogen system can operate at a specific fuel consumption less than 3 lb per hp hr and as low as 2 lb per hp hr for a hydrogen/oxygen system. The oxygen is added primarily to increase the available heat and further improvements in specific fuel consumption can be realized by recuperating exhaust heat and using it to preheat the fuel mixture. Because the vehicles operate in a vacuum, high pressure ratios are readily available for the hydrogen or hydrogen/oxygen engines.

Because of the heat and friction losses inherent in their design, positive displacement piston type engines have been replaced by multi-stage turbines giving efficiencies in excess of 70%.

Mr. Breaux went on to outline the serious problems encountered in the design of the fuel tanks for these systems. The preferred method of storage uses high pressure low temperature tanks as these are not affected by zero g conditions and are less complex than low pressure liquid storage systems.

In conclusion, Mr. Breaux stated that the field of non-propulsive power systems was one of increasing activity and a lot of progress has yet to be made.

In the lively question period which followed the lecture, Mr. Breaux was asked if he could give a figure for the volume of liquid hydrogen to be carried for a given power output. In replying, on behalf of Mr. Breaux, Mr. Schultz said that one application with which he was familiar required 100 lb of hydrogen and oxygen to supply 20 hp for 5 hours. Dr. MacPhail provided the

highlight of the question period by enquiring if any thought had been given to using hydrogen in its solid state as part of the missile structure. Mr. Breaux replied that many things were known about hydrogen, but not its tensile strength!

Evening Session, February 19th
Electronics

Reported by W. E. Cunningham

The subject of this session was "Fast Pulses and Semiconductors". The speaker, Professor N. F. Moody, Professor of Electrical Engineering, University of Saskatchewan, was introduced by F/L K. Weinstein.

Professor Moody commenced his talk by demonstrating the need for fast pulse techniques which apart from assisting the physicist also have a wide application in industry in computing machines and automation. Initially physical lengths or intervals of time were considered in terms of relatively large units: inches, centimeters and seconds. Steady progress in the realms of physics, atomic physics and allied sciences has, however, created a need for new and much smaller units of measurement; thus, for example, we now have the micron (10^{-4} cm) and the microsecond (10^{-6} sec). In order to be able to measure any interval of time it is necessary to define the boundaries (start and finish) of the interval. An interval of one second may be measured by means of a pendulum. As the interval to be measured becomes less and less, however, it is necessary to find some other means of defining its boundaries and this has led to the development of fast pulse techniques. As a typical example of the very small intervals that can now be measured, the speaker mentioned the average life of radioactive particles. He explained that as a radioactive substance gradually degenerates it liberates pulses of energy — the intervals between successive pulses are often less than one microsecond (10^{-6} sec). These pulses can now be counted and time intervals between successive pulses measured by means of a device known as a scintillation counter.

In atomic physics, the pulses which must be measured often have very small energy levels and it is essential to amplify them so that they may be displaced on suitable counters or indicators. In order to reproduce and amplify a fast pulse successfully, an amplifier must have a very wide pass band (0-300 Mc/s). The distributive amplifier has been developed to meet this requirement; the salient features of this type of amplifier were outlined by the speaker.

Turning to transistors, Professor Moody stated that certain types were being used extensively for fast pulse triggering, especially in the computer field. "Turn on" times of better than 10 milli-microseconds (10^{-8} sec) had been achieved employing the "avalanche" technique; in this application during operation the transistor is greatly overloaded but since the duration of the overload condition is extremely small, failure of the transistor does not occur. The physical properties of the transistor were outlined. Some of the materials (germanium, gallium-arsenide, silicon) and manufacturing processes were mentioned, in particular the importance of doping impurity concentration at the surface of the semiconductors.

The speaker concluded his talk with a brief but very interesting explanation of the manner in which the wave form of a fast pulse can be displayed on an oscilloscope using the strobe technique.

Electronics Session: Prof. N. F. Moody (l) and F/L K. Weinstein (Chairman)

An input signal (fast pulse) is used to trigger a strobe pulse generator. The strobe pulse from the generator is then used to obtain an instantaneous pulse height sample of the input signal which is suitably delayed. During successive input signals, the strobe pulses progressively sample different sections of the input pulse waveform; this is achieved by means of a linear ramp and dc step voltages which progressively delay the strobe pulses with respect to the input signals. Each voltage sample is amplified and displayed on an oscilloscope in the form of a dot. In this manner the waveform of a fast pulse (10^{-9} sec) may be displayed as a series of dots on an oscilloscope with time base set to one micro second.

Throughout the lecture slides were used to illustrate miscellaneous circuits and performance characteristics.

During question time some aspects of the Japanese Esaki tunnel diode were discussed. This diode has inherent high frequency capabilities and will be used as a negative-resistance element. A discussion on the probability of errors occurring caused by small time delays introduced by circuit elements became very involved.

The session was well attended, bearing in mind that it took place on a Friday evening (8.30 pm) after a full day of other lectures and meetings.

Morning Session, February 20th
Operations

Reported by C. C. Young

The Session was chaired by Mr. R. N. McCollum, District Manager, Sperry Gyroscope Co. of Canada, who introduced the first speaker, Mr. J. A. Gillies of Canadian Pacific Air Lines.

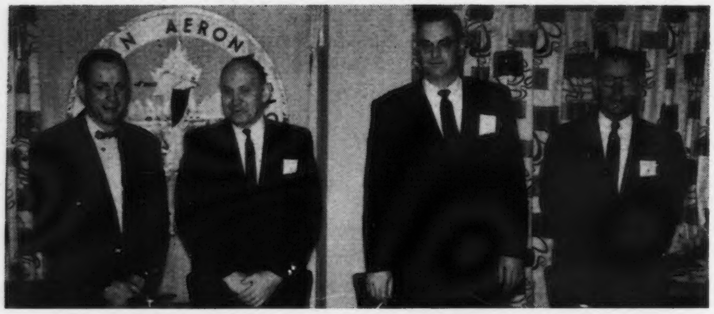
Mr. Gillies' paper was entitled "Reliability in Airline Operations; How do we obtain it?" and the speaker commented that this title was not worded as he had intended, the words "How do we obtain it" being better replaced by "How can we obtain it". He said that dependability, safety and reliability were the key factors in operations and that passengers were often unsympathetic when delays occurred; it seemed to him that some passengers were only interested in leaving the departure point and gave little thought to the possibility of arriving at their destination!

Turning to the causes of delays, the speaker said, in CPAL operations, maintenance problems accounted for 42% of all such delays. These problems had to be tackled and eliminated as far as possible since the alternative, a standby aircraft, could be very expensive unless the frequency of service was high.

Mr. Gillies gave examples of maintenance problems relating to the Britannia and showed by diagrams how CPAL had solved these, firstly by close liaison with the manufacturer at the time of construction, secondly by careful attention to snags, and thirdly by a planned maintenance programme divided into a series of periodic checks. He showed examples of work logs and indicated how these were integrated with a system of coloured cards. He said that suggestions and observations made by CPAL employees were welcomed and remarked that these had been very useful.

A number of slides were shown to illustrate the defect rates of the subsystems of the Britannia and to underline the speaker's remarks on the "delays-vs-defects" concept.

Mr. Gillies concluded his paper by observing that maintenance was an attempt to anticipate troubles and that careful design with maintenance problems in view was the basis for reliability.



Operations Session: (l to r) Mr. R. N. McCollum (Chairman), Mr. I. J. Kessler, Mr. J. A. Gillies and Mr. A. F. MacDonald

After a brief question period, the Chairman thanked Mr. Gillies for his able presentation and introduced the second speaker, Mr. I. J. Kessler, USAF, whose paper was entitled "Comments on the Evolution of Aircraft Maintenance Concepts".

Mr. Kessler began by outlining early maintenance procedures and said that because of the design concept most maintenance used to be done in situ which was expensive and immobilized the aircraft for long periods. He thought that this type of maintenance had also led to much over-maintenance, which in turn led to the "repair and replace" concept.

Mr. Kessler went on to show how performance analysis could provide a constant survey of trouble sources and illustrated his remarks with slides giving overhaul patterns for the DC-6, DC-7 and Convair 340. He outlined the different degrees of overhaul and commented on the relative merits of the "return to zero" and "make serviceable" concepts, particularly with regard to USAF experience of the IRAN concept which, he said, had been found unsuitable for production line overhaul work.

Turning to electronics equipment, the speaker said that this had been found to suffer from random failures and experience had generally shown that if a piece of electronic equipment was functioning satisfactorily the best practice was to leave it alone.

Mr. Kessler concluded his paper by listing the ground rules for the evaluation of non-mechanical items.

The session was by this time running somewhat behind schedule and discussion of Mr. Kessler's excellent lecture had to be limited. After thanking Mr. Kessler, the Chairman introduced the third speaker, Mr. A. F. MacDonald, De Havilland Aircraft of Canada, whose subject was "Design and Development of the STOL Airplane".

Mr. MacDonald commenced by stating that his talk was strictly non-technical, and went on to outline the development of the De Havilland Beaver and Otter, and to show how these "bush types" had found world-wide acceptance in military and civil applications. He cited some examples of operations in which the ruggedness of the STOL aircraft had contrasted with the delicacy of comparable helicopters, and had enabled the STOL aircraft to do their work whilst the helicopters were plagued by unserviceabilities.

Despite the controversial nature of the paper, discussion had to be limited in order to show a well presented colour film of the operation of the Caribou. The Chairman then thanked Mr. MacDonald and the session was concluded.

Afternoon Session, February 20th
Propulsion

Reported by J. G. Portlock

The Session Chairman, W/C W. N. Hoye, introduced the first speaker, Mr. T. H. Cooper, Assistant Chief Engineer of Canadian SKF Company Limited, whose subject "Recent Advances in Ball and Roller Bearings" began with a short history of ball and roller bearings from the latter half of the 19th Century until the present time.

The application of "rotating element" bearings to gas turbines accelerated design and development, and brought many new problems.

Rotating element bearings, made from SAE 52100 steel had been found satisfactory for reciprocating engine bearings, but as their upper operating temperature limit was only 350°F, they were not suitable for some applications such as gas turbines. Therefore, new materials had to be found.

The speaker discussed the properties of two of the newer bearing materials, M50, recommended for temperatures up to 600°F, and M1, for temperatures up to 800°F. New bearing materials produced in North America are required for strategic reasons not to have a high tungsten content – their high temperature characteristics had to depend on alloying the steel with chromium, molybdenum and vanadium. As regards bearing cages, silicon-iron-bronze material had been found satisfactory for temperatures up to 600°F.

Vacuum melting of M1 and M50 steels, though costly, had been found to produce good results in preventing subsurface occlusions, but no apparent advantage had been noted in vacuum melting SAE 52100 steels.

Given suitable high temperature materials for the construction of the rotating element bearing, the upper operating temperature limit depended on the type of lubrication used.

During the question period which followed Mr. Cooper's talk, the speaker was questioned on the use of teflon in bearing separators, miniature bearings, fatigue life of bearings, bearing grinding techniques for the newer materials and bearing lubrication. The speaker satisfactorily answered all these questions with the exception of the one on miniature bearings. These, he said, are in a class of their own, and he felt that he was not in a position to discuss them.

At the Dinner

At the conclusion of the question period, Mr. Cooper was thanked by the Chairman for a most interesting and informative talk.

The next paper in the Session was presented by Mr. G. Rosen, Chief of Analysis, Hamilton Standard Division of United Aircraft Corporation, entitled "New Problem Areas in Aircraft Propeller Design". Mr. Rosen began his talk with a short history of propeller development from the early wooden types to those in production today.

He felt that there would be a need for propellers for a long time to come, especially on transports required to carry large payloads at comparatively low speeds – speeds at which propeller driven aircraft had superior performance. Performance requirements would, however, be more stringent in the future.

The speaker said that blade reversing had enabled landing runs to be reduced by 40%, and that synchronizing and synchrophasing of propellers had reduced noise levels by 10 db. It was no longer the practice, he said, to buy propellers "off the shelf" for a particular installation, the optimum propeller design having to be developed for each particular application. Exotic blade shapes for high speed use brought structural problems. The best approach seemed to be by cutting blade thickness ratios. Propellers for aircraft in the subsonic range would have to have ultra-thin supersonic blades. Problem areas at present were in the design and development of propellers for long duration turboprop aircraft, high speed long range aircraft, high speed attack aircraft and STOL aircraft.

High cambered airfoils are showing promise though at the moment their cruising characteristics are not satisfactory.

Propulsion Session: (l to r) Mr. G. Rosen, W/C W. N. Hoye (Chairman) and Mr. T. H. Cooper

There is need for development in variable blade cambers, a new range of airfoils, possibly operating the propeller in a shroud and larger diameter propellers of lighter construction. New light and strong materials for propellers would also have to be developed.

The attachment of the propeller to the engine could be improved. A 10% weight saving could be achieved by using nose mounted propellers, while if the engine reduction gearing could be incorporated into the propeller, the weight saving could be as much as 30%.

More sophisticated propeller control systems would have to be developed such as the automatic negative thrust control, beta control, lock pitch, and acceleration sensitive governor, which are already in operation in turboprop aircraft. As propeller design develops, more safety features will be required.

The speaker felt hopeful that all these problems would be solved, and was confident that propellers were here to stay.

After a question period dealing with maintenance problems on hollow steel blades, fatigue life on propeller blades, contra-rotating propeller blade shapes and Russian progress on propeller design, the speaker was thanked for a very interesting paper by the Chairman.

At one of the technical sessions

At the beginning of the Open Forum, the Chairman made a few introductory remarks as to the purpose and method of conducting the Session and then called for questions from the audience.

The discussion of the subject Fuels and Oils ranged from protective coatings on engine parts, the problems of the petroleum industry in meeting stringent specifications and the problems of engine manufacturers, when their engines are operated on fuels from different suppliers.

There appeared to be signs that the engine manufacturers and the petroleum industry did not always see eye to eye in these matters, but the Session did bring out that both sides have their own problems.

After some discussion on the recently reawakened interest in manpowered flight, the subject turned to the question of the availability of small powered engines for ultra-light aircraft and powered gliders.

A/C Gouin observed that an altitude of 19,000 ft had been achieved in 1923 with an Avro Baby aircraft with an engine of only 2½ hp. *Mr. Boyd* said that nothing seems to have been done for many years to make such an engine available. *A/C Gouin* felt that there was a need for a 5 to 10 hp engine, and that one should be developed. *W/C Hoye* suggested that a Diesel engine could be produced in small powers, but *Mr. Boyd* did not agree. He said that experience with Diesels as aircraft powerplants had been most disappointing. *Dr. MacPhail* said that he felt that small engines need not be smaller models of large engines – why not a steam engine?

There was general agreement that in recent years with so many developments in large powerplants, the need for a small powered engine for ultra-light aircraft had been completely overlooked, forcing enthusiasts to adapt automotive engines to aircraft use.

The Chairman then thanked the participants in the Open Forum and said that he felt it had been a successful experiment. The Session was then adjourned.

BRANCHES

NEW BRANCH

The Council has approved the establishment of a new Branch of the Institute in Quebec City.

A meeting of members of the Institute resident in the Quebec area was held in the Talon Vaults on the 3rd March to consider the desirability and feasibility of forming a Branch and, if the decision was favourable, to elect an Executive Committee. Between 35 and 40 people were present, most of them non-members who were interested in the proposal; Mr. H. C. Luttman, the Secretary of the Institute, also attended the meeting.

Mr. L. A. Dickinson, who had arranged the meeting, opened it with a short explanation of its purpose and then asked Dr. J. J. Green to tell the meeting something of the Institute's background and history. This he did in some detail, from the prewar days of the Ottawa Aeronautical Society to the present. Dr. Green concluded by pointing out that breadth of membership interest was fundamental to the Institute and that it was quite natural that it should now be extending its scope to the problems of space flight and exploration. In this connection he emphasized that Canadian contributions to "near space" research were already very significant and likely to increase and that Quebec City, and particularly CARDE, should be able to play a useful part in the Institute's work in this field.

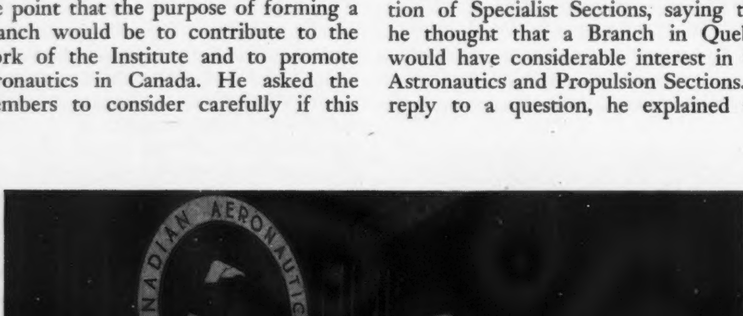
Some of the Branch members discussing future plans after the meeting

Dr. C. H. Nicholl followed. He made the point that the purpose of forming a Branch would be to contribute to the work of the Institute and to promote aeronautics in Canada. He asked the members to consider carefully if this end could be accomplished in Quebec; like Dr. Green he believed it could.

The last speaker was Mr. Luttman, who talked about his experience with the formation of other Branches. He said that there had usually been initial difficulties in attracting the requisite number of 20 members – there seemed to be a natural check at 17 or 18 – but, once a Branch had been established and a programme of meetings had got under way, the membership had invariably increased rapidly. There were already 20 members in Quebec and he was confident that others would join when there was a local organization to serve them. He also described the organization of Specialist Sections, saying that he thought that a Branch in Quebec would have considerable interest in the Astronautics and Propulsion Sections. In reply to a question, he explained the Institute's relations with the American Rocket Society, the Canadian Astronautical Society and the Astronautical Society of Canada, and said that negotiations were currently in progress between the CAI and CAS with a view to closer association. There was some discussion of a general nature and Mr. Luttman answered a number of questions.

Finally Mr. Dickinson asked some of the members present to express their opinions and, though a few difficulties were foreseen, in such matters as the procurement of speakers, the consensus was strongly in favour of going ahead. Accordingly the members separated themselves from the guests and elected an Executive Committee comprising: Dr. H. M. McMahon, Chairman; Mr. L. A. Dickinson, Vice-Chairman; Mr. F. Jackson, Treasurer, and Dr. C. I. H. Nicholl, Secretary. The Branch did not elect a member of the Council at this time.

These results were announced by Mr. Dickinson and the meeting was adjourned.



Quebec Branch Executive Committee
(l to r): Dr. C. I. H. Nicholl, Secretary; Mr. L. A. Dickinson, Vice-Chairman; Dr. H. M. McMahon, Chairman, and Mr. F. Jackson, Treasurer

NEWS

Ottawa

Reported by Dr. P. M. Millman

February Meeting

The monthly meeting of the Branch was held in the RCAF Officers' Mess on Gloucester Street on Wednesday, the 24th February, under the Chairmanship of Mr. G. D. Watson, Vice-Chairman of the Branch.

Some fifty members heard a most interesting talk by Dr. G. de Vaucouleurs of the Harvard College Observatory

who was introduced by Mr. D. O'Donnel, Chairman of the Programmes Committee.

The speaker gave a most interesting talk on the atmospheres of Venus and Mars.

Dr. de Vaucouleurs summarized the present knowledge concerning the physical conditions existing in the atmospheres of our two neighbour worlds, Mars and Venus. They present a marked contrast. The atmosphere of Venus has a large content of carbon dioxide and probably some nitrogen, but little else is known concerning other possible constituents. Mars, on the other hand, has nitrogen as the chief constituent in its atmosphere, and less than 4% the quantity of carbon dioxide found on Venus. The atmosphere of Mars also contains small quantities of argon and water vapour.

Attention was called to the absorption bands recently observed in the spectrum of both the light and dark hemispheres of Venus. Some of these have been tentatively identified with carbon monoxide and molecular nitrogen, but a number remain unidentified. The extensive observations of the occultation of Regulus by Venus in July, 1959, have given us a scale height for the upper atmosphere of Venus which is just a little smaller than that found in the lower atmosphere of the earth.

The mysterious character of the blue haze on Mars was noted. No adequate explanation has yet been advanced for the occasional clearing of this haze over major portions of the planet's surface. It was stated that, as a result of bands observed in the spectrum of Mars between 3 and 4 microns, it is now generally agreed that the presence of some form of plant life on this planet has a high degree of probability.

After a short discussion period, the speaker was thanked on behalf of those present by Dr. P. M. Millman.

Winnipeg

Reported by C. P. Gulland

February Meeting

The February dinner meeting of the Branch was held in the Winnipeg Flying Club on Tuesday the 23rd.

After dinner, the Chairman, Mr. B. W. Torell, opened the meeting with a few remarks about the current membership drive and asked the membership for contributions for the Journal. Following these remarks Mr. Torell called on Mr. D. C. Marshall to introduce the speaker of the evening.

The speaker, Mr. C. E. B. McConachie, Manager, Sales Engineering Department of Canadair, commenced his paper "The CL-44D and Air Cargo" with some complimentary remarks about the RCAF and the part they played in the development of the CL-28 (Argus) and of the CL-44.

By means of slides, Mr. McConachie described various features of the aircraft mentioning in particular the fuselage dimensions and the swing tail mechanism. The fuselage design is such that an object 84 ft long and of constant cross-section may be loaded. The swing tail locking mechanism incorporates interlocks which prevent the throttles being opened if any of the eight hydraulic actuated locks are open. In addition to the automatic safety feature a means is provided for visual checking of the latches before flight. The powerplant assembly, which is built around a Rolls-Royce Tyne, 5730 eshp, twin spool, turboprop engine, has been designed as a quick change unit.

The main feature of the CL-44 is its economic capability. The speaker pointed out that the direct operating costs for 3,000 mile stage lengths is 3.75c per ton mile. From this figure he showed that the aircraft could operate at a profit with a 75% load factor at a figure as low as 10c per ton mile. A figure which is competitive with surface transportation.

Canadair has developed three types of loading and unloading systems, one of which is capable of handling a turnaround flight in 63 minutes. The handling of the 65,000 lb pay load in this time is accomplished by the use of pallets. The pallets are 7 ft 6 in long and are made of ½ in plywood aluminum faced. The load is built up on the pallets and carried to the aircraft on a loading platform. The off load is drawn out of the aircraft on to the platform and then the new load is slid off the platform into the aircraft. Barrier nets capable of withstanding a 9g load may be secured between the pallets.

Mr. McConachie's enthusiasm for the CL-44 and the future of air cargo was not dampened by the deluge of questions which followed his talk.

Mr. J. M. MacTavish thanked the speaker on behalf of the membership for his most interesting and informative paper.

Vancouver

Reported by J. W. Whiskin

February Meeting

The Annual Joint CAI/SAE meeting was held on February 15, 1960, in the Georgia Hotel. Of the 64 members and guests present, only 14 were CAI members. This was the worst turnout since the Branch was formed and those absent missed one of the season's most interesting evenings.

Refreshments were served at 6.30 pm, courtesy of the Ethyl Corp. of Canada and dinner was served at 7.00 pm. The meeting was opened by SAE Chairman, Mr. L. Coulthard, who presented Mr. T. W. "Tommy" Siers with a 25 year plaque. Mr. Siers, who is the SAE Aviation Representative and a former member of the Vancouver Branch, introduced the speakers for the evening; they were, Mr. E. Levin, Manager of Dyna-Soar System Growth Section, and Dr. F. Werner, Biophysics Unit Chief of Space Medicine Section, Boeing Aero-Space Division.

On the subject "Space Flight", Mr. Levin traced developments from the Chinese solid fuel rockets of 1300 AD through the gasoline and air V-1's, the oxygen and alcohol V-2's, the oxygen and kerosene Atlas to the newest "Minute Man" missile powered by a solid fuel engine. In addition to the problems of power and control, launching and flight, we were told of the great effort to solve the problems of re-entry.

Dr. F. Werner, on the subject "Bio-Scientific Research for Space Flight", discussed many of the human frailties that must be compensated for in design. Among these many problems and the interesting developments to overcome them were excessive noise level up to 200 decibels, vibration, acceleration, vision impairment, radiation and isolation. A film showing human reaction to weightlessness followed. A lively discussion period showed the immense interest in the exploration of space.

The speakers were thanked by Mr. R. Keith of the SAE.

Montreal

Reported by W. H. S. Bird

February Meeting

The regular monthly meeting was held in the Airlines Restaurant, Montreal, on February 17, 1960, Branch Vice-Chairman, Mr. F. C. Phillips, presiding. 76 attended the dinner including 35 guests and several members of the Students' Section. 160 attended the lecture.

Unfortunately, the scheduled speaker, Mr. A. Newton, Chief Project Engineer of Rolls-Royce, Derby, England, was unable to be present, however his talk was very ably presented by Mr. S. Taylor, Sales Engineer of Rolls-Royce, Canada. Mr. Taylor was introduced by Mr. C. Davidson and showed a number of excellent slides which outlined the history and development of the by-pass engine particularly as represented by the Rolls-Royce Conway engine.

He mentioned that there was nothing new about the ducted fan and the by-pass engine – Whittle had patented the basic principle in 1940 and the Metropolitan Vickers Company had tested one before 1950. Rolls-Royce became interested in 1946 and their original BJ.80 engine of 8,000 lb thrust developed, in 1947, into the original Conway engine which first ran in 1952. The Conway had weathered a considerable storm of criticism, however it was now felt that it has proven to be an excellent engine. The experiments in arriving at optimum conditions of by-pass ratio, turbine entry temperature, pressure ratios etc were referred to and a typical by-pass engine as represented by the Conway was described along with the thrust reversing system. On the Conway, reverse thrust of about 50% of the corresponding forward thrust could be achieved.

The various parameters going to make up the jet engine were discussed. These included thrust, specific fuel consumption, installed weight (including nacelle intake and exhaust systems), price, reputation of the manufacturer and noise.

Various slides showed how specific fuel consumption is affected by increasing by-pass ratio, the effect of bleed losses, pod drag, silencer losses etc. It appeared that by-pass ratios should not be much outside the range 0.7 to 1.1 and it was mentioned that with the higher ratios, intake noise might become more severe largely due to higher fan tip speeds.

Rolls-Royce believe in the principle of mixed exhaust, that is the by-pass air should be directed into the main jet stream, this being stated to provide improved performance due to the increase of propulsive efficiency with one common stream as compared with two streams at different velocities.

The increase in operating flame temperature was shown to increase the efficiency, and temperatures as high as possible were desirable, consistent with reliable operation. Adequate cooling can only be obtained by experience and new features are being constantly incorporated. It was estimated that by the time their latest engine is running, Rolls-Royce will have accumulated nearly three million hours.

Although hampered by not having written the paper, and not being too familiar with some of the technical details, Mr. Taylor did a good job of answering – or parrying – such questions as how Rolls-Royce selected basic parameters, particularly when comparing pod versus buried engine installations where drag values for instance could be considerably different.

Mr. Taylor was thanked for a very interesting and informative presentation by Mr. T. A. Harvie.

Toronto

Reported by G. F. de Jersey

February Meeting

Tuesday, 16th February, 1960, was somewhat of a gala night for the Toronto Branch, since this was not only the Annual Student Thesis Night, but in addition we had great pleasure in welcoming to our Meeting both the President and the Secretary.

Dr. MacPhail and Mr. Luttman arranged to break their journey to Edmonton, where they were to attend the Mid-season Meeting.

Dr. J. H. T. Wade, the Branch Chairman, opened the meeting by welcoming the audience of 50 members and guests to the Institute of Aerophysics, University of Toronto. He then outlined the programme for the evening, which by its very nature, differed from our usual functions. A paper was to be presented by each of the three finalists chosen from the University of Toronto fourth year Engineering Physics Course (Aeronautics Option), in competition for the CAI Bronze Medallion. A Certificate of Merit, one year's free membership in the CAI and a cheque were to be given to each contestant. The Chairman mentioned that each speaker would be introduced by a member of the Faculty of the Institute, who in turn would introduce the subject about which the student would talk.

After an intermission, and before the decision by the judges, awards would be made to the top students in aeronautical subjects from both Ryerson and Central Technical Institutes.

Dr. G. K. Korbacher of the Institute introduced the first speaker, Mr. W. J. Scott, whose paper was titled "A Study of the Annular Jet".

Mr. Scott's paper caused considerable interest, particularly in view of the many current experiments conducted with VTOL and Hovercraft vehicles, where the study of the annular jet has assumed the greatest importance. The speaker referred to the work conducted in this field by ONERA, Avro, and NASA, and commented upon the known results obtained, particularly with reference to the problems of stability and control, two items which in themselves require considerable future research.

Dr. Korbacher spoke very highly of Mr. Scott as an honor student during his introduction; this was well reflected in the very fine paper this speaker presented.

Professor B. Etkin, commenting upon Mr. A. A. Sonin's paper titled "Re-entry into the Earth's Atmosphere", stated that as usual the U. of T. was way ahead of the times, since the paper concerned the re-entry of a manned vehicle!

Professor Etkin took pains to point out that none of the papers prepared by these students were taken from their courses at the University, but that each student had been forced to delve out the information from available sources on his own initiative.

Mr. Sonin's extremely well presented paper, dealt with many facets of the problems confronting re-entry. These included studies on the effect of heat, acceleration, angle of approach, available lift etc and covered the vehicles of the three main categories under study at NASA, i.e. ballistic capsules, winged gliders and a kite-like inflatable vehicle. This latter was mentioned as having collapsible lifting surfaces, allowing control at extremes of altitude. Except for its inherently frail structure, this glider indicated a most promising re-entry vehicle.

Dr. G. N. Patterson, Head of the Institute, introduced the final speaker, Mr. R. J. J. Taborek, whose paper was titled "Transfer of a satellite from one planet to another".

In his remarks, Dr. Patterson stated that this imaginative paper would take the audience from the problems of the immediate future, to one which might well be of concern in another age. The increase in the world's population, being assisted by medical research, could project this problem into focus sooner than is realized!

Mr. Taborek's paper concerned the problems confronting the provision of an atmosphere suitable for human existence on the planet Mars. The speaker explained that Mars could be visualized as being similar to the Sahara, but at an altitude of 50,000 ft. By diverting one of Jupiter's moons – specifically VI, thought to be mainly composed of ice – from its present influence to that of Mars, an atmosphere would be created which would provide sufficient water vapor content to raise the present extremely low temperature, ground pressure and absorb the dangerous solar radiation. Mr. Taborek's calculations revealed that this transfer was feasible if regulated to three phases. The first phase would be the transfer from Jupiter's influence to a solar orbit, the second a shift from the solar to a Martian orbit, and finally to Mars itself. It is

probable that the satellite would disintegrate on contact with Mars' atmosphere, at which time it would simply fall as rain or snow.

After the intermission the student recommended for his outstanding work at Central Technical Institute was presented with a book prize suitably embossed with the CAI emblem. Mr. J. P. Uffen of De Havilland Aircraft, an ex-Central Tech student, presented the prize to Mr. Seigfreid Schrattner.

Mr. S. L. Britton of Orenda presented a CAI embossed book prize to Mr. J. R. Kniseley of Ryerson Technical Institute, for his work on a thesis entitled "Aluminum Alloys in the Aircraft Industry".

The judges, Messrs. G. F. Kelk, R. M. Sachs and Dr. G. W. Johnson were then asked by the Chairman for their decision. Mr. Kelk explained that the papers had not only been judged for their technical excellence, but also for their presentation. The high standard attained by the three speakers had made the judging particularly difficult; however Mr. A. A. Sonin had been chosen as the recipient of the CAI Bronze Medallion, with runners up W. J. Scott and R. J. J. Taborek judged equal in sharing second place honours.

The Chairman invited the President to present the Medallion on behalf of the CAI and afterwards closed the meeting by reminding the audience of the next Branch Meeting, scheduled for the 24th March in the De Havilland Cafeteria, at which time Mr. E. V. Claxton will present a paper on the General Electric J.79 Engine and its installation in the F-104 fighter.

SECTIONS

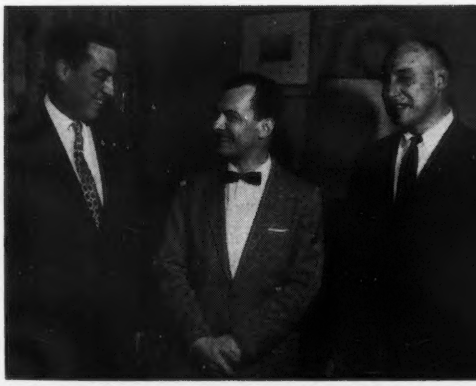
ASTRONAUTICS

Montreal

Reported by J. B. Ogle

February Meeting

A dinner meeting of the Astronautics Section of the Institute was held in Montreal on the 23rd February at the Canadair plant to hear a most interesting lecture from Dr. G. H. de Vaucouleurs the noted French astronomer. Dr. de Vaucouleurs, who discussed the Atmospheres of the planets Mars and Venus, has had a distinguished career in many parts of the world and is at present a Research Associate at Harvard College Observatory in Cambridge, Massachusetts. 57 members came to the dinner, which was presided over by the Section Chairman, Mr. D. Bogdanoff, and were joined by a further 40 when the meeting adjourned to the lecture room.



H. H. Whiteman (l), Dr. G. H. de Vaucouleurs and D. Bogdanoff (r)

Astronomy in general has been and still is a highly speculative science, with a steady stream of different hypotheses being put forward in an attempt to explain what is known from the continuously accumulating volume of observations. In his lecture however, Dr. de Vaucouleurs ably demonstarted how speculation about the atmospheres of our two nearest planets is giving way to a consistent body of information which can be deduced from the observational data. A clear outline was given of the modern techniques which the astronomer now uses in studying the planets, including spectrographic analysis and the measurement of the rate of fading of a star across which the planet passes when viewed from the earth. Dr. de Vaucouleurs gave the meeting a full account of the properties of the Martian and Venusian atmospheres which have been deduced with the aid of these techniques; and those present who knew little of the subject beforehand came away with an authoritative report on the established facts.

In thanking Dr. de Vaucouleurs for his excellent presentation, Dean D. L. Mordell of McGill University drew attention to the large number of questions put forward following the lecture which was a sure testimony to the interest which the speaker has aroused.

COMING EVENTS

CAI

24th and 25th May—*Annual General Meeting,* Chateau Laurier, Ottawa.

IAF

15th-20th August—*XIth International Astronautical Congress,* Stockholm, Sweden.

ICAS

12th-16th September—*Second International Congress in the Aeronautical Sciences,* Zurich, Switzerland.

BRANCHES

Vancouver

30th April—*Annual General Meeting.*

Ottawa

11th May—158 Gloucester St., *Annual General Meeting and Film Night.*

Halifax-Dartmouth

27th April — CPO's Mess, HMCS Shearwater, *Annual General Meeting.*

Winnipeg

10th May — Winnipeg Flying Club, *Truth Without Consequences,* Dr. P. J. Sandiford.

14th June — Winnipeg Flying Club, *Annual General Meeting.*

MEMBERS

NEWS

R. D. Richmond, F.C.A.I., formerly Vice-President, Missile and Systems Division, Canadair Limited, has recently taken the appointment of Vice-President, Operations, Canadian Pratt & Whitney Aircraft Company Limited.

R. J. Higman, A.F.C.A.I., who was Director of Manufacturing in Canadair's Missiles and Systems Division, has been appointed its Director of Operations.

R. G. Raven, A.F.C.A.I., formerly Engineering Manager of Canadair's Missile and Systems Division has been appointed its Director of Engineering.

G. A. Jones, M.C.A.I., has recently taken the position of General Manager, Colson Corporation, Jonesboro, Arkansas.

DEATH

It is with deep regret that we record the deaths of **Mr. M. W. MacLeod, A.F.C.A.I.** and **Mr. D. H. Whittaker, Technical Member.**

Mr. M. W. "Mac" MacLeod, who died on the 12th December, 1959, was Chief Development Engineer for Trans-Canada Air Lines and former McCurdy Award winner for 1954.

Mr. D. H. Whittaker was, at the time of his death, a Technical Illustrator with the De Havilland Aircraft of Canada Limited.

OBITUARY

Mr. M. W. MacLeod

Mr. Merlin W. "Mac" MacLeod, Associate Fellow of the Canadian Aeronautical Institute, died on Saturday the 12th December, 1959.

The death of Mac MacLeod, Chief Development Engineer, Trans-Canada Airlines, is most regrettable, particularly so as he was just about to enjoy a few years of leisure.

Mac was a mechanical genius. In addition to being inherently ingenious, he seemed to remember every mechanism he ever saw. When confronted with a problem he could remember something he had seen thirty or forty years ago in a lumber camp, on a locomotive, on a racing car, or somewhere else and adopt the principle of operation to solve a current problem. He also had the unusual ability of thinking 'simply'; he could devise jigs and tools that were remarkable in their simplicity of design, accessibility and usability.

Mac could not be surpassed in his knowledge of welded structures – particularly those subject to severe temperature and shock conditions. Through his redesigns, he could invariably increase the service life of any engine exhaust system from a few hundred hours between overhauls as it came from the manufacturer to several thousand hours between overhauls.

In addition to Mac's mechanical ingenuity he was a quiet-spoken individual who always wanted to help everyone. I doubt if anyone ever heard Mac raise his voice in vexation or anger. He, like many people, had many causes for feeling frustrated at times but the only outward reaction would be one of disappointment or sorrow that the other person could not see the advantages of adopting his suggestion.

The best proof of Mac's wonderful character was the fact that everyone liked him; to have everyone as a friend and to have no enemies is indeed an achievement we can all envy.

Mac's passing is like writing finis to the pioneering era of aviation in Canada and TCA in particular. Although the Company has long since moved out of its pioneering days, Mac was an outstanding link between the famous north country mechanics with the ingenious methods of the early days and the engineered and production controlled methods of today. The Company and we as individuals are very much the loser with his retirement and death.

"Mac" MacLeod has passed away. But he leaves a record of achievement second to none in the world of civil aviation.

He lived and worked according to his own philosophy – "If it's good, let's make it better."

Montreal — J. T. Dyment

ADMISSIONS

At a meeting of the Admissions Committee, held on the 15th March, 1959, the following were admitted to the grades shown.

Associate Fellow

E. J. Lynch (on transfer from Member)
R. J. McWilliams (on transfer from Member)

Member

G. M. Georgas (on transfer from Technical Member)
LCDR M. C. J. Major (regraded from Technical Member)

Technical Member

P. N. Adams (on transfer from Student)
C. K. Meadley (on transfer from Student)

Student

O/C D. M. Anderson, Canadian Services College, Royal Roads, B.C.
W. G. Beeby, Provincial Institute of Technology and Art, Calgary, Alta.: *3227 - 27th St. S.W., Calgary, Alta.*
G. A. Brown, Provincial Institute of Technology and Art, Calgary, Alta.: *2343 - 23rd St. N.W., Calgary, Alta.*
F. A. Christie, Nova Scotia Technical College, Halifax, N.S.: *68 Walnut St., Halifax, N.S.*
R. W. Doel, Provincial Institute of Technology and Art, Calgary, Alta.: *6308 Bowood Dr., Box 276, Bowness, Alta.*
G. D. Elliott, Provincial Institute of Technology and Art, Calgary, Alta.: *1503 - 11th Ave. N.W., Calgary, Alta.*
K. Farrell, Nova Scotia Technical College, Hailfax, N.S.: *137 Walnut St., Halifax, N.S.*
O/C C. Gottlieb, Canadian Services College, Royal Roads, Victoria, B.C.
O/C K. W. Gough, Canadian Services College, Royal Roads, Victoria, B.C.
O/C A. W. Horne, Canadian Services College, Royal Roads, Victoria, B.C.
T. A. Iles, Provincial Institute of Technology and Art, Calgary, Alta.: *Box 774, Bowness, Alta.*
A. Klammer, Provincial Institute of Technology and Art, Calgary, Alta.: *1415 - 18th Ave. N.W., Calgary, Alta.*
O/C J. V. Koziak, Canadian Services College, Royal Roads, Victoria, B.C.
O/C J. F. Kroeger, Canadian Services College, Royal Roads, Victoria, B.C.
A. P. Lange, Provincial Institute of Technology and Art, Calgary, Alta.: *Box 846, Grande Prairie, Alta.*
T. A. Lesnik, Provincial Institute of Technology and Art, Calgary, Alta.: *1109 - 20th Ave. N.W., Calgary, Alta.*
R. H. Logie, Provincial Institute of Technology and Art, Calgary, Alta.: *726-18th St. N.W., Calgary, Alta.*
E. F. Loyek, Provincial Institute of Technology and Art, Calgary, Alta.: *2227-25th Ave. N.W., Calgary, Alta.*
E. Lukan, Nova Scotia Technical College, Halifax, N.S.: *88 North St., Halifax, N.S.*
J. R. McLeod, Provincial Institute of Technology and Art, Calgary, Alta.: *2227 - 25th Ave. N.W., Calgary, Alta.*
J. A. Partica, Provincial Institute of Technology and Art, Calgary, Alta.: *611 - 18th Ave. N.W., Calgary, Alta.*

O/C J. R. Pickering, Canadian Services College, Royal Roads, Victoria, B.C.

J. R. Pretty, Provincial Institute of Technology and Art, Calgary, Alta.: *612 - 6th Ave. S.W., Calgary, Alta.*

R. R. Radke, Provincial Institute of Technology and Art, Calgary, Alta.: *1607 - 20th Ave. N.W., Calgary, Alta.*

J. D. Smith, University of British Columbia, Vancouver, B.C.: *468 E. 45th Ave., Vancouver 15, B.C.*

M. Stollar, McGill University, Montreal, P.Q.: *5578 Waverley St., Montreal, P.Q.*

J. St. Pierre, Ecole Polytechnique, Université de Montréal, Montreal, P.Q.: *10375 Clark St., Montreal, P.Q.*

B. W. Templeton, Provincial Institute of Technology and Art, Calgary, Alta.: *1617 Bowness Rd., Calgary, Alta.*

G. Vilcsak, Provincial Institute of Technology and Art, Calgary, Alta.: *419-20th Ave. N.E., Calgary, Alta.*

R. H. Wheatley, Provincial Institute of Technology and Art, Calgary, Alta.: *466 - 22nd Ave. N.W., Calgary, Alta.*

SUSTAINING MEMBERS

Canadair Limited have announced that fuselages for the Canadair Forty Four, the all-cargo swing-tail turboprop transport, which Canadair is building for three major cargo carriers in the United States, will undergo static and fatigue tests in a special water tank now under construction.

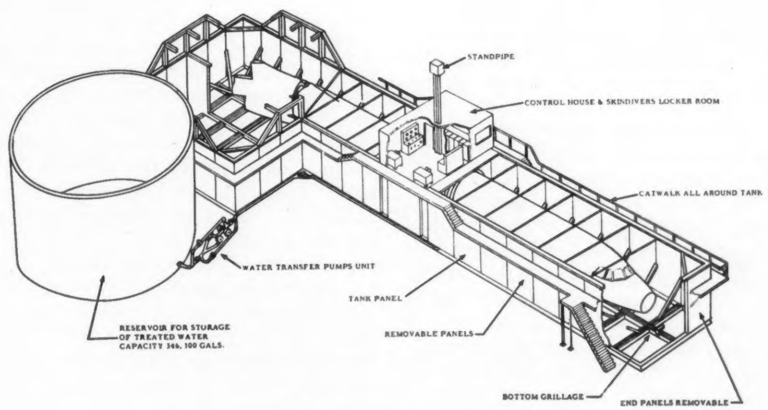
This tank, first of its kind in Canada, will be a little over 141 ft long, to accommodate the 138 ft fuselages, and 23 ft wide with a side extension of 33 ft at one end to make room for the airplane's swinging tail.

Water, to a depth of 16 ft, will be drawn from or returned to an adjoining reservoir, as required; the reservoir will be 50 ft in diameter and 30 ft high, with a capacity of 346,300 gallons.

Design of the tank and reservoir was carried out by Canadair's engineering laboratories and the static and fatigue testing will be done by members of the company's structural test section. A Montreal firm, Dominion Bridge Company, is building the tank at a cost of $140,000. The entire program is expected to cost more than $1,000,000 and will continue through 1961.

The forward section of the fuselage is scheduled to go into the tank early in May of this year, and the rear section in July. Maximum stresses representing a normal operational flight can be imposed on the test fuselage within six minutes. Cumulative stresses equivalent to a period greater than the useful life of the airplane can be reproduced in the tank test in a period of months.

The water-tank method of testing fuselages was devised to apply cabin pressures representing the differentials at various altitudes. If air instead of water were to be used, its high compressibility could convert a minor failure to an explosive breakup of the entire specimen, thus endangering personnel and property and, by the extent of damage, hide the origin of the failure.



A sketch of Canadair's new water tank

In addition to the pressure tests in water, the tank will be drained for the application of various external loads to the swing-tail; the loads will be applied by means of hydraulic cylinders and linkages to represent the stresses to which the aircraft will be subjected in service both in flight and on the ground. During the tests, the tail will be swung open and shut thousands of times, under weights, to prove its performance.

Water employed in the tank tests will be treated before use, to prevent its having a corrosive effect on the specimens and to minimize reaction between the aluminum of the fuselage and the steel of the tank.

Tank-testing of airframes to guard against the onset of metal fatigue came into practice a few years ago as the result of disasters to the first series of jet transports. Millions of dollars have been spent in experiments to discover the conditions which caused these airplanes to disintegrate in the air. The results of these tests prevent the possibility of such failures in subsequent aircraft.

Bristol Aero-Industries Limited have announced that its Aviation Services Division has been awarded a contract for the ramp handling and line maintenance of Air France L-1649 and B-707 aircraft at Montreal Airport. The contract takes effect on the 1st April, 1960.

This follows the recent announcement of the signing, by Bristol and British Overseas Airways Corporation officials, of a contract for the handling by the Aviation Services Division of the Corporation's aircraft at Montreal and Toronto Airports.

BOOKS

Progress in Metal Physics — Vol. 7. Edited by BRUCE CHALMERS. Pergamon Press, New York, 1959, 408 pages. Illus. $16.00.

"This annual series presents authoritative reviews of the existing state of knowledge in specialized aspects of the field, including both physical metallurgy and metal physics. Each volume discusses a few subjects of current interest" – thus states the inside of the fly-leaf.

If to this is added the titles of the subjects discussed viz:

(1) Equilibrium, Diffusion and Imperfections in semi-conductors.
(2) The Physical Metallurgy of Titanium Alloys.
(3) Thermodynamics and Kinetics of Martensite Transformations.
(4) The stored energy of cold work.
(5) The properties of metals at low temperatures.

the potential reader will have a good idea of the possible value to him of this highly academic work.

The subject matter of this book is handled with a galaxy of mathematical formulae and physical terms which is the common language of the present day physicist who is pursuing the fundamentals of metals and for whom this book is written. Undoubtedly, the acquisition of this and the preceding six volumes would provide a metal physicist with references of very considerable value.

The editor is to be congratulated on his selection of subject matter which, as is their wont, is varied and covers a wide field in the realm of metal physics.

To the practical metallurgist or engineer who is concerned with the day to day problems of handling metals in their varied types and forms, and who is concerned with their application in aircraft structures and engines, this book would prove to be of little or no value. The chapter headed "Physical Metallurgy of Titanium Alloys" would probably whet his appetite, but a study of this section shows that he would be rapidly deluded as, in keeping with the rest of the book, the method of handling this subject is almost entirely concerned with the physics rather than the metallurgy of Titanium alloys, and comparatively little of a practical nature is concerned even with those alloys which are now used in a commercial sense, the rest of the alloys which are discussed have as yet no commercial value.

This same criticism concerning the manner of handling the subjects of this book is intended to be regarded as a comment, not in a derogative sense, but to warn metallurgists that they will find very little that they can get their teeth into as the book is intended almost entirely for the metal physicist.

R. SMALLMAN-TEW

Introduction to Stress Analysis. By CHARLES O. HARRIS. Brett-Macmillan Ltd., Ont., 1959. 330 pages. Illus. $7.50.

"The field of engineering steadily becomes more scientific and mathematical, and our basic engineering courses must be a part of this development." Little quarrel can be had with such an introductory statement in the author's Preface. The agreement, however, may become less unanimous when the author sets out to present "more of theory and less of empiricism, leaving the empirical matters to the course in Machine Design and Structures and to engineering experience". To this reviewer, who thinks that the reputed conflict between theory and empiricism is merely a ghost born from unclear thinking, these statements smack of the current trend to teach fundamentals at the exclusion of more practical knowledge.

Fortunately, the book is not quite as radical as the Preface would imply, and yet it manages to present its subject matter in a modern way. After a preliminary chapter devoted to a short review of Statics, a rather thorough introduction is given to the main topic of plane stress and strain. The following seven sections discuss applications of the basic relations to elementary cases of stress distribution. In this, one misses a uniform treatment of arches and rings through which a student would be led to master the techniques of statically indeterminate analysis. On the other hand, less conventional topics such as simple problems in plates and shells (membrane theory) and solids of revolution (e.g. rotating disks) have been included. The decried empiricism comes to life with a vengeance in a chapter on factors which affect strength and deformation of materials; a little is said there about theories of failure, fatigue, stress concentration, creep and relaxation, impact and temperature effects. The aeronautical engineer would have liked to see a few words about fail-safe structures. A final chapter on elementary theory of plasticity discusses limit design as applied to simple cases. Further matter is to be found in a series of appendices, among them some elements of the theory of elasticity.

The book has the great merit of clarity of style and exposition, and is provided with excellent illustrations. A profusion of well-organized problems (some illustrative and some to be proposed as exercises) should prove an invaluable help to the instructor. Among the shortcomings, there seems to be some inconsistency in judging the mental receptivity of the student. To give an example, why should the proof of the basic beam relation $V = dM/dx$ between transverse force and bending moment be classified among the difficult problems (and why is it not given in the text), when only a few pages later the reader is asked to understand the much more complicated equations of stress equilibrium? And should the student, supposedly able to express a problem as a partial differential equation, be given such artless definitions as "torsion is twisting", or "flexure is bending"? The organization of the subject matter is perhaps a matter of individual taste, however there does not seem to be any good reason for not placing the section on shear and moment diagrams immediately after the review of Statics. The short appendix on dry friction seems to be somewhat out of place in this book.

It would appear that the analysis of stresses is only one aspect of the question of assessing a structure from the point of view of its strength. For this reason "Structural strength analysis", or even the old-fashioned "Strength of Materials", would seem to be a better title – but that may be a personal prejudice.

The reviewer hopes these remarks will not cast too deep a shadow upon the undisputed value of a well-presented textbook.

E. KOSKO

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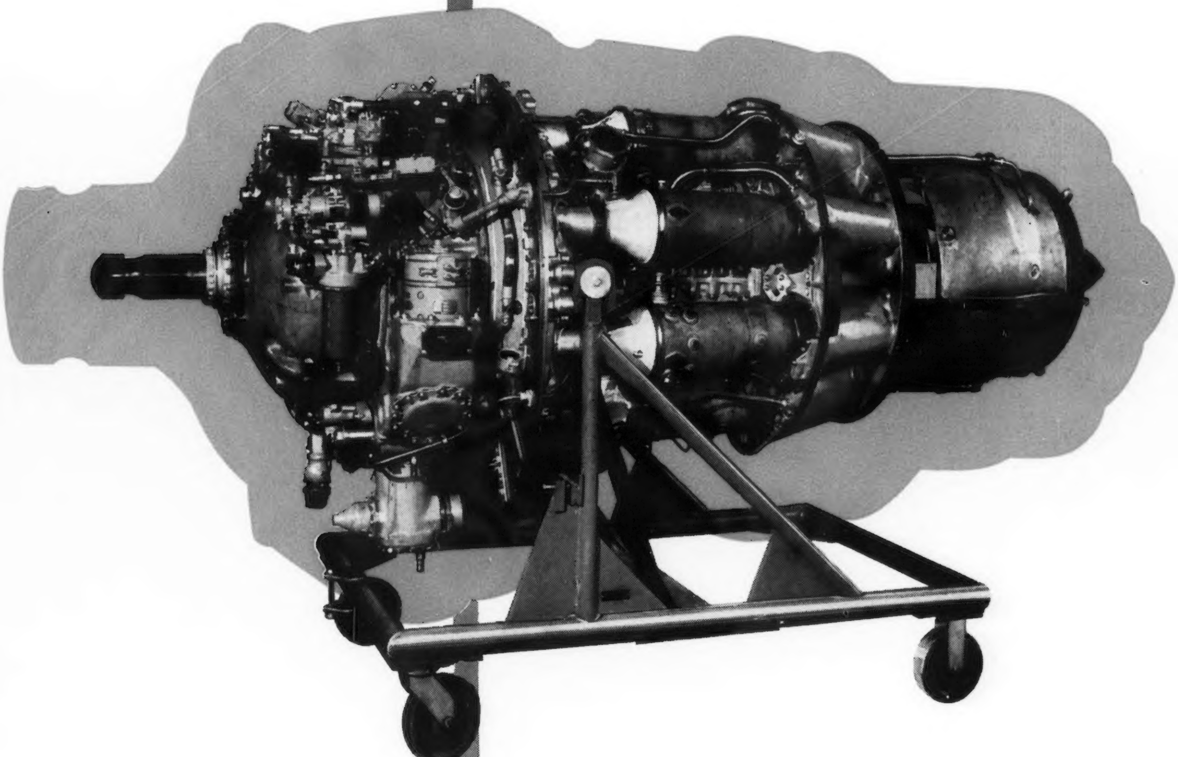

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